PATT40 Liverpool 2023
Pupils' Attitudes Towards Technology Conference

Diverse Experiences of Design and Technology Education for a Contemporary and Pluralist Society

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Alison Hardy, David Morrison-Love.

PATT40

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Edited by:
Dr Sarah Davies
Nottingham Trent University
Dr Matt McLain
Liverpool John Moores University
Dr Alison Hardy
Nottingham Trent University
Dr David Morrison-Love
University of Glasgow

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Welcome

Dear PATT40 delegate,

It is with great pleasure that I welcome you to Liverpool for the 40th International PATT conference. On behalf of the conference organising committee and Liverpool John Moores University (LJMU), we are delighted to host the 2023 conference. PATT40 is set to be a stimulating and collegiate event, which will add valuable evidence and perspectives to the Technology Education community, bringing together cutting-edge research from around the world from the plurality of curricular experiences.

LJMU is a distinctive, unique institution, rooted in the Liverpool City Region but with a global presence. Our students and staff, past, present, and future, are the beating heart of our city and can be found in every corner of every industry and community. We couldn't exist anywhere else and have shaped this place we belong to. The School of Education has a long history of teacher education and has strong partnerships with local schools. I would like to acknowledge and thank Professor Joe Yates, Dean of the Faculty of Arts, Professional and Social Studies, and Dr Ceri Daniels, Director of the School of Education, for their support of both the conference and our collective research endeavours.

The PATT40 conference theme, *"Diverse Experiences of Design, Technology and Engineering Education for a Contemporary and Pluralist Society"* advances our research focus on design and technology praxis that contributes to a quality experience for learners. The 2023 sub-themes were developed to capture the uniqueness, diversity and plurality of our subjects and the impact that they children and young people, and society. The conference will reflect the sub-themes exploring axiological, epistemological, and ontological issues in theory and practice. Plenary sessions will draw together different perspectives, reflect on tensions and frame future research, discourse, and enquiry.

PATT is all about the community of past, present, and future researchers. It is about you. It is about us. We celebrate equality, diverse and inclusion, seeking to nurture early career research and foster a plurality views and experiences. We welcome delegates from 18 different countries across 5 continents, bringing their insights to bear on local, national, and international problems and opportunities. From as far west from Liverpool as the USA and as east as Japan. From Norway to South Africa. PATT40 welcomes a growing and diverse community of technology education researchers.

Our thanks and appreciation go to Technology Supplies Ltd, who sponsored a scholarship to support a teacher of design and technology in the UK to attend the conference.

Finally, I would like to acknowledge the PATT40 organising committee for their commitment and diligence in planning for the conference. It has been a genuine pleasure and privilege to work with a group of people who are passionate about developing and improving design, technology, and engineering education. I thank them most sincerely.

Have an inspiring, challenging and reaffirming conference experience!

Yours sincerely,

Matt McLain (Conference Chair)

Follow us @PATT40Liverpool on Twitter (X), Instagram and Threads; and post using the hashtag #PATT40 #PATT40Liverpool or #PATTupNorth

A Note from The Editorial Team

It has been an honour to oversee and engage with the diverse community of writers and researchers who contributed to the PATT40 conference proceedings. We extend our sincere gratitude to the initial team of reviewers for their diligent work in peer reviewing abstracts, which served as the catalyst for our peer review process, safeguarding and upholding the conference's quality standards.

In line with our commitment to equality, diversity, and inclusion, we introduced a novel approach to the full-paper peer review process. This approach welcomed participation from all authors, regardless of their experience or background. This initiative resonated with our team's dedication to ensuring that everyone had an equal opportunity to benefit from the review process. We firmly believe that this approach has bolstered our mission to nurture early career research and has allowed us to publish a collection of papers that reflect the diverse range of perspectives and experiences within our community.

The editorial team

Sarah Davies, Matt McLain, Alison Hardy, and David Morrison-Love

Conference Theme

The main theme for PATT40 is *"Diverse Experiences of Design, Technology and Engineering Education for a Contemporary and Pluralist Society"*, inviting delegates to present original research and scholarship exploring axiological, epistemological, and ontological aspects of the subject. Four sub-themes break the theme down into strands focusing on *philosophy and culture* (Strand I), *curriculum, pedagogy, and assessment* (Strand II), *evidence-based practice* (Strand III) and *teacher education and development* (Strand IV):

I. Diverse and inclusive ways of knowing and being in design and technology;

II. Exploring and advancing teaching and learning for design and technology education;

III. Measuring impact of design and technology education in and beyond the classroom;

IV. Approaches to teacher preparation and development in design and technology education;

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Conference Papers

Unveiling Biases: An Exploration of ChatGPT-3.5-generated 'Technology Stories'

Cecilia Axell, Linköping University, cecilia.axell@liu.se
Johan Boström, Linnaeus University, johan.bostrom@lnu.se

ABSTRACT

A technology that is increasingly affecting our daily lives is artificial intelligence (AI). An example of such a technology is ChatGPT-3.5, which has received a lot of attention recently. ChatGPT-3.5 is a text generator that is developed on a large number of existing texts. Currently, there is a debate about negative consequences in education, for example, if students let the chatbot write texts for them. In this study, however, our point of departure is on how ChatGPT-3.5 and storytelling can be used as a tool in teacher education to develop students' critical thinking in relation to technology.

A main objective of technology as a school subject is to prepare pupils to act in a technology-intensive world, which includes critical thinking about technology and its impact on individuals, society, and nature. However, a critical aspect of technology education is that it easily becomes an unreflective doing without a meaningful context. A way to circumventing this problem is to use storytelling in technology teaching.

This is a pre-study for a coming project aiming to let teacher students create stories using ChatGPT-3.5 and then critically analyse the technological content in the stories. In this pre-study, we gave ChatGPT-3.5 the instruction to generate ten shorter stories for children with a focus on technology. A qualitative content analysis shows that there are several dominant themes within the stories, and that the chatbot presents a view of technology that is mainly positive and without any critical reflection on its effects on individuals, nature and society. Furthermore, in the stories, high-tech male coded technology is a dominating theme. The pre-study highlights the importance of critical thinking and reflections when using AI tools in technology teacher education. It also indicates that stories generated by a chatbot can be a steppingstone to visualise technology bias and contribute to developing teacher students' critical gaze.

Keywords: Technology Education, ChatGPT-3.5, Storytelling, Critical Thinking

1. INTRODUCTION

A main objective of technology as a school subject is to prepare pupils to act in a technology-intensive world, which includes critical thinking about technology and its impact on individuals, society, and nature (Skolverket [The Swedish National Agency for Education], 2022). However, a critical aspect of technology education is that it easily becomes an unreflective doing without a meaningful context (Skolinspektionen [The Swedish Schools Inspectorate], 2014). A way to circumventing this problem is to use storytelling in technology teaching (e.g., Axell, 2017; Svensson et al., 2019). However, for a story to be used in technology teaching, the teacher first needs to do a critical reading in order to identify what messages about technology it conveys (Axell, 2015; 2017). On the basis of this, in a previous study (Axell & Boström, 2021), we investigated the technological content in a selection of picture books. The results showed that in the books, there is a focus on how separate artefacts function but no detailed explanation of how these artefacts are connected or what kind of implications they have in a societal context. There was also an emphasis on traditionally masculine coded technology.

A technology that is increasingly affecting our daily lives is artificial intelligence (AI). An example of such a technology is ChatGPT-3.5, which has received a lot of attention recently. ChatGPT-3.5 is a text generator that was developed on large amounts of texts. Currently, there is a debate about negative consequences in education, for example, if students let the chatbot write texts for them. In this study, however, our point of departure is on how ChatGPT-3.5 and storytelling can be used as a possible tool in teacher education to develop students' critical thinking.

ChatGPT-3.5 has received a lot of attention since its launch in the fall of 2022 and the number of users exploded, reaching one million in the first week. Using artificial intelligence, the chatbot can answer questions and conduct advanced reasoning. ChatGPT can be used to generate summaries of texts but also things like creating poems or stories. The AI tool has created a great debate among journalists, writers, artists but also among schoolteachers because of its limitless capacity for cheating. Others believe that chatbots such as ChatGPT-3.5 also offer many opportunities for teachers and that it is therefore important to learn both its limitations and its possible uses (Ahlgren et al., 2023; Mhlanga, 2023).

However, ChatGPT-3.5 has learned everything it 'knows' by 'reading' books, articles, websites, research papers, user-generated content, and many other publicly available written texts. This means that it can be said to reproduce values and bias when it creates texts. Chatbots are a relatively novel technology, and not much research has examined the messages in chatbot-generated texts aimed at children. The first children's book created by AI, *Alice and Sparkle* (Reshi, 2023), was published in January 2023, and the first Swedish language AI children's book, *Trisse Traktor* (Fernholm, 2023), was released in March.

We have not found any research on bias in ChatGPT-generated texts aimed at children or children's literature written by ChatGPT. Therefore, we asked ChatGPT-3.5 to generate 'technology stories' for us in order to compare them with the findings in Axell and Boström (2021).

This study is to be considered as a pre-study to having teacher students analyse 'technology stories' they create by using ChatGPT. Our starting point is that, for their coming role as technology teachers, teacher students need to develop skills to critically review a text created by chatbots. In this pre-study, we are the ones analysing the technology content in stories generated by ChatGPT-3.5.

2. AIM AND RESEARCH QUESTIONS

Our aim is to investigate how ChatGPT-3.5 frames technology when creating children's stories with a technology focus. More specifically, we aim to answer the following questions:

- What are the representations of technology in stories generated by ChatGPT-3.5?
- What views of technology are presented in the stories generated by ChatGPT-3.5?

3. LITERATURE REVIEW

3.1. *What is ChatGPT-3.5?*

ChatGPT-3.5 is an artificial intelligence (AI) chatbot released in 2022 by OpenAI. The name "ChatGPT" derives from "Chat", which refers to its chatbot functionality, and "GPT", which stands for "Generative Pre-trained Transformer". 3.5 is the version number of the ChatGPT. ChatGPT-3.5 is trained on data up to June 2021. Which is described by OpenAI as being able to generate natural language tasks (such as creative writing, summarisations and conversation) and code through instructions (i.e., prompts) (OpenAI, 2023 5th of April).

3.2. *AI, ChatGPT and bias*

Artificial intelligence (AI) systems have raised concerns about bias and discrimination due to how hard it is to see 'into' the system and their reliance on historical data (Roselli et al., 2019). AI algorithms can perpetuate existing biases present in the data they are trained on. AI algorithms, including machine learning techniques, learn from historical data that may encode biases, making it challenging to eliminate unwanted bias completely (Roselli et al., 2019). This raises concerns about the fairness and equity of AI systems.

While ChatGPT is capable of generating human-like responses, concerns have been raised about biases in its outputs. The platform has produced nonsensical, factually incorrect, and offensive responses, raising questions about its neutrality (Singh & Ramakrishnan, 2023).

For example, political biases have been observed in ChatGPT, with a preference for left-leaning viewpoints identified in political orientation tests (Rozado, 2023). Gender biases have also been found in language models like GPT-3, where feminine characters are associated with stereotypes and portrayed as less powerful than masculine characters (Lucy & Bamman, 2021).

The presence of biases in ChatGPT underscores the need for increased awareness and scrutiny of biased AI systems (Rozado, 2023). Efforts to address bias include incorporating social, ethical, and legal principles into AI systems to enhance their ability to recognise and mitigate discrimination (Ferrer et al., 2021).

Educating students about AI systems and their limitations is crucial for developing critical thinking skills. Students should be encouraged to challenge the outputs of ChatGPT and develop the ability to analyse and discern reliable information (Mhlanga, 2023). Educators play a significant role in fostering an informed and responsible relationship between humans and AI. By teaching students about bias in AI and its limitations, educators can promote ethical and responsible use of AI, empowering students to navigate the evolving technological landscape (Mhlanga, 2023).

To sum up, bias in AI systems, including ChatGPT, is a pressing concern for fairness and equity. Addressing bias requires increased awareness, scrutiny, and the development of detection and mitigation methods. Educating students about the nature of AI, the limitations of systems like ChatGPT, and the skills needed to critically analyse AI-generated content is essential for promoting responsible and ethical use of AI in society.

3.3. How technology is depicted in children's stories written by humans

Axell and Boström (2021) investigated what kind of different portrayals of technology could be found in 180 books aimed at the age groups 1 to 6. Through a thematic analysis they identified three overarching themes: *Autonomous technology; Triumphant technology;* and *Technology as an enabler.*

The theme of *Autonomous technology* revolves around technology acting without human guidance. The books for younger children focused mainly on traditionally masculine-coded technology, with little context or human interaction. The books for the older age group depicted anthropomorphised technology and included human interactions, but the focus on masculine-coded technology persisted.

The second theme, *Triumphant technology*, deals with the historical aspect of technological development. In the books, modern technology was presented as superior to older technology, and there was often a focus on Western advancements. Environmental perspectives were largely absent from the books, but in the cases where they did exist, they primarily focused on the benefits of technological advancements.

Technology as an enabler, the third theme, revolves around technology as a result of human needs and desires. Technology is in this case depicted as relating to various everyday contexts, such as house construction and different systems (e.g., transport systems, energy systems). The theme also deals with vocational roles. The books under investigation primarily showed male characters in traditionally masculine-coded occupations, and thus often reinforced gender stereotypes.

4. METHODOLOGY

The data for this study consists of ten original stories. These stories were generated using the ChatGPT-3.5 language model (specifically text-davinci-002) and resulted in a diverse range of narratives and perspectives for analysis. We prompted ChatGPT-3.5 with the following:

> "Could you write me a story for children that focuses on technology, a minimum of 500 words, please."

After each story was generated, a new chat was generated to create a blank slate for the chatbot to create a completely new story and not be affected by the last one.

The ChatGPT-generated stories were analysed by using a qualitative content analysis to search for patterns. As described by Erlingsson and Brysiewicz (2017) and Hsieh and Shannon (2005), a qualitative content analysis is a repeated and interpretive process in which the meaning of a part can only be understood as related to the context. Based on the research questions, the objective was to identify recurring themes in stories. The analysis was carried out in the following steps:

(i) *Familiarisation:* The first step was to familiarise with the data, which meant a reading and re-reading of the stories generated by ChatGPT.

(ii) *Initial categorisation by ChatGPT:* To initiate the content analysis, ChatGPT was utilised to perform the initial categorisation of themes present in the stories. This process generated a preliminary set of thematic categories.

(iii) *Researchers' stance and refinement:* Following the initial categorisation, we critically engaged with ChatGPT's output. We took an active role in shaping and refining the categorisation; we questioned and challenged the initial categorisation, ensuring that the themes accurately represented the underlying content of the stories. This critical engagement allowed us to establish our stance and exert control over the analysis process.

(iv) *Final categorisation:* With our stance established, a final set of thematic categories was determined. These categories were carefully defined, ensuring clarity and coherence. Any discrepancies or disagreements were discussed and resolved through consensus, and we reviewed and refined the categorisation until a satisfactory level of agreement and consistency was achieved.

(v) *In-depth analysis:* After finalising the thematic categories, an in-depth analysis of each category was conducted, which involved a comprehensive review of the stories, extracting relevant excerpts and examples that exemplified the identified themes.

(vi) *Comparative analysis:* In this stage, we compared the findings from the qualitative content analysis with the findings in Axell and Boström (2021).

(vii) *Integration and synthesis:* The final step involved integrating our analysis and insights with the initial categorisation provided by ChatGPT. By combining the automated categorisation with the critical perspectives and our analyses, a more comprehensive and nuanced understanding of the themes and their implications was achieved.

(viii) To ensure transparency and credibility (validity) of the study, consistent documentation and systematic analysis were maintained throughout the process.

5. RESULTS

The analysis of the stories generated by ChatGPT-3.5 revealed several prominent themes and sub-themes. The following section presents the results organised by each theme and its corresponding sub-themes.

5.1. Theme 1: Technology is high-tech/A.I.

Sub-themes: Robots, Self-driving cars, Computers and software

The sub-themes within this theme, including robots, self-driving cars, and computers and software, highlight the transformative potential and advanced nature of technology. These narratives illustrate the capabilities of artificial intelligence and high-tech systems, showcasing their efficiency and automation. However, they do not problematise the complex relationship between humans and machines. There is a lack of nuanced picture of power dynamics, biases, and ethical dilemmas.

5.2. Theme 2: Technology is connected to sustainability

Sub-themes: Wind turbines, Solar panels, Recycling

The sub-themes under this theme emphasise the positive relationship between technology and sustainability. These narratives highlight the potential of renewable energy and eco-friendly practices to address environmental challenges. However, the stories do not convey the unequal distribution of sustainable technologies and a need for systemic change and collective action.

5.3. Theme 3: Science fiction technology/gadgetry

Sub-themes: Teleporter, Make-a-wish 3D-printer, Time machine

The sub-themes revolve around imaginative and futuristic concepts. These narratives capture the human fascination with innovative technologies and the potential they hold for transforming our lives. While they inspire awe and curiosity, they often overlook the potential negative consequences and unintended effects that arise from their implementation, such as energy and material consumption, and ethical dilemmas.

5.4. Theme 4: Technology makes the world a better place

Sub-themes: Sustainable development, Creating economic growth, Safety and health, Historical Advancements

The sub-themes within this theme, including sustainable development, creating economic growth, safety and health, historical advancements present technology as a force for positive change and a techno-optimistic perspective. The stories do not show the unequal distribution of technological benefits and the potential for technology to exacerbate existing social inequalities.

5.5. Theme 5: Technology replaces humans

Sub-themes: As a cultural producer, As a friend, As a problem-solver

The sub-themes under this theme highlight the evolving relationship between humans and technology. These narratives explore the potential of technology to automate tasks, offer companionship, and solve complex problems. However, implications for employment, social connections, and human agency in a world increasingly shaped by automation and artificial intelligence is not highlighted.

5.6. Theme 6: Technology as a career enabler

Sub-themes: Knowledge of coding, Becoming a captain of industry, With a little technology and a lot of hard work

The sub-themes within this theme, including knowledge of coding, becoming a captain of industry, with a little technology and a lot of hard work, shed light on the role of technology in career paths. Though, the stories oversimplify the challenges and complexities of navigating technological career paths, downplaying the structural barriers (such as male dominance in the high-tech industry) and inequalities that individuals face.

5.7. Theme 7: Technology as a fountain of joy

Sub-themes: Going on adventures, Creating a friend for oneself, Winning competitions

The sub-themes within this theme highlight the positive and joyful experiences associated with technology. The stories overlook the potential social, psychological, and ethical challenges that arise from excessive reliance on technology for fulfillment and happiness.

6. DISCUSSION

In this study, we explored how ChatGPT-3.5 frames technology when creating stories for children with a technology focus. By analysing the generated stories, we identified several prominent themes which to some extent can be connected to the three themes found by Axell and Boström (2021).

6.1. Autonomous technology

One of the themes that emerged from the analysis is the portrayal of technology as high-tech/AI. The stories generated by ChatGPT-3.5 prominently featured robots, self-driving cars, and computers and software. These narratives depict the transformative potential and advanced nature of technology, emphasising its efficiency and automation.

Additionally, the theme of technology replacing humans emerged from the analysis. These narratives explore the potential of technology to automate tasks, offer companionship, and solve complex problems. However, the stories may oversimplify the complexities of human-machine interactions and fail to address the implications for employment, social connections, and human agency. This relates for example to Ellul's (2010) view of technology, i.e., technological advancements are proceeding at such a rapid pace that humans must automatically adapt and accept these changes.

6.2. Triumphant technology

Another theme that emerged is the connection between technology and sustainability. These narratives showcase a positive relationship between technology and sustainability. However, as Robinson (2004) notes, sustainability should not be reduced to technological fixes but rather requires broader systemic changes. It is important to consider the socio-political dimensions and potential trade-offs involved in the deployment of sustainable technologies. The theme of technology making the world a better place showcases a view that as long as we develop new technology everything is going to be alright. As Winner (1986) points out, society often becomes entranced by the possibilities offered by technology, overlooking the broader implications and power dynamics embedded within it.

The theme of science fiction technology/gadgetry also emerged from the analysis. These narratives reflect the human fascination with innovative technologies and their potential to transform our lives. While the stories generated by ChatGPT-3.5 inspire awe and curiosity, they may overlook the potential negative consequences and ethical dilemmas that arise from the implementation of such technologies.

6.3. Technology as an enabler

Furthermore, the themes of technology as a career enabler and as a fountain of joy emerged. These narratives highlight the role of technology in career development and success. However, the tech industry is heavily gendered. Consequently, as Faulkner (2001) highlights, through portrayals of technology and its associated occupations, gender stereotypes are reinforced. Therefore, it is crucial to consider whether the narratives in the stories perpetuate existing gender biases or challenge them.

7. CONCLUSIONS

A comparison with the results in Axell and Boström (2021) shows that the themes identified in that previous study are similar to the themes in this study. However, some differences were identified, for example that the ChatGPT-generated stories portray an even narrower picture of what technology is. Thus, the problem with these stories is the lack of a broader view of technology, like this quote from one of the stories may exemplify: *"As Timmy grew older, his love for technology only continued to grow. He started to read books and watch videos about how to code and build different devices. He also started to attend robotics and coding classes in his school."*

In summary, this pre-study highlights the importance of critical thinking when using AI generated texts in technology teacher education. The next step is to initiate a study where technology teacher students generate their own stories, using ChatGPT-3.5, and then let them analyse the stories by using the results from Axell and Boström (2021) and the present study as a framework. Based on the students' analyses, we will explore if and how Chat-GPT-generated 'technology stories' could support students critical thinking in relation to technology.

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Subject Specific Pedagogy in Technical Vocational Education: the Implementation of a New Way of Teaching

Jan Axelsson, Karlstad University, jan.axelsson@kau.se
Nina Kilbrink, Karlstad University, nina.kilbrink@kau.se
Stig-Börje Asplund, Karlstad University, stig-borje.asplund@kau.se

ABSTRACT

Research regarding classroom pedagogy of subject specific contents in the field of technical vocational education is scarce, nationally in Sweden, but also in an international perspective. This paper presents results from a Swedish action research project and it aims at exploring the process of a learning study, which deals with the settings in MIG/MAG welding and the intervention of the new pedagogic approach CAVTA (Conversation Analysis and Variation Theory Approach). The empiric material consists of video recorded welding education in a workshop and documented meetings in a welding teacher team. The theoretical toolbox of CAVTA permeates the teaching and learning processes as the teachers in the intervention try to implement patterns of variation in the planning, enactment and evaluation of the teaching and learning processes. In combination with the variation theoretic principles embedded in the teaching, ideas inspired by conversation analysis are implemented – the main element being an enhanced interaction, thus enabling for the students to display their understanding of the subject specific contents. The results show how CAVTA can be integrated in the teaching of settings regarding MIG/MAG welding, so that certain aspects of the object of learning is visualized. Furthermore, the findings show how the integration of CAVTA support the manifestation of a student's understanding of the object of learning. How variation and the use of several senses and simultaneous different semiotic resources are activated as essential components in the teaching and learning processes, is made explicit in the paper. Plans for a recently launched research project including several different technical vocational education programs are also presented. The lack of classroom studies regarding technical vocational education calls for exploration in research, but should not avoid the ambition of development. This study captures the design and the development of a new pedagogic approach. Our hope is that the study will contribute to a growing body of knowledge within the field of technical vocational education and spur on further studies in this field of research.

Keywords: technical vocational education, CAVTA, action research, learning study

1. INTRODUCTION AND PREVIOUS RESEARCH

It is hard to estimate the quantity of welders around the world, but figures imply that the number is overwhelming. Merely the number of welding jobs in the USA was estimated to be 428 000, in 2021 (United States Department of Labor, 2023). However, recent educational research regarding welding has almost exclusively focused on the introduction of virtual reality technology (Huang et al., 2020; Rodríguez-Martín & Rodríguez-Gonzálvez, 2019; Torres et.al, 2017). It is important to conduct more studies focusing on the actual teaching and learning processes in the area of authentic practical welding and education of new welders. The focus of this study is school based practical welding education in a workshop, and thus it contributes with knowledge in a neglected area of research.

Researchers and a team of welding teachers have co-operated in the project *Learning to weld in vocational education*[1] to contribute with knowledge regarding what happens in teaching and learning situations in the workshop of Swedish practical welding education at an upper-secondary school and this paper focuses on the third and final year of the project. More specifically, the aim of the paper is to explore the process of a learning study, which deals with the settings in MIG/MAG welding and the intervention of the new pedagogic approach CAVTA (Conversation Analysis and Variation Theory Approach). In the paper we focus on the research question:

How can tools from CAVTA provide support for the teaching of settings regarding MIG/MAG welding?

2. THEORETICAL FRAMEWORK AND METHODOLOGY

CAVTA as a pedagogic approach and an analytical tool was inspired by Emanuelsson's and Sahlström's (2008) ideas of combining conversation analysis and variation theory in educational research. Ten years later Asplund and Kilbrink (2018), explored the combination of the theoretical perspectives in educational research of vocational education, and in the research project *Learning to weld in vocational education*, they went even further and formed the new pedagogic approach CAVTA (Asplund & Kilbrink, 2020; Kilbrink & Asplund, 2020). The basis of CAVTA is the position that learning includes the dimensions contents (what is to be learned), and process (how something is learned). The interaction between the person learning something, and the person teaching the contents, is given great importance in CAVTA. Conversation analysis mainly contributes with instruments regarding the how aspect, and the variation theoretical toolbox is mainly linked to the what aspect. With CAVTA, Asplund and Kilbrink found a way to explore how a combination of conversation analysis and variation theory could function as ”as a fundamental point of departure in teachers' work on planning, executing and evaluating their own teaching” (Asplund & Kilbrink, 2020, s.4).

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2.1. Conversation analysis

Conversation analysis is an approach to study the interactional organization of social activities. It is often described as having a radical departure since it tries to describe and analyze the actions participants do, and how these actions, that are by and large intersubjectively recognizable, are perceived and oriented to by other participants. Thus, what CA studies is how participants produce an action and how they display their understanding of each other's actions and what this generates in terms of new actions (Goodwin, 2000; Hutchby & Wooffitt, 1998; Sahlström, 2011; Schegloff, 1997, 2007). As interaction is examined as a site where intersubjective understanding about what a speaker means to accomplish is created and maintained (Heritage & Atkinson, 1984), a key feature in CA is to examine how participants arrive at a shared understanding through publicly displayed verbal and embodied conduct (Mondada, 2013). Hence, CA uses representations of the interaction in the form of detailed transcriptions of talk and other conduct, as well as digital video frames or drawings of visual phenomena. However, CA has not only been used as a method to study social interaction; it has also been applied in concrete and actual contexts (Antaki, 2011), and this also concerns how CA is used as a pedagogic approach. The intervention of this study includes the use of CA in the analytic phase of the video recorded teaching sessions and how the teacher enables interaction in the actual teaching and learning situation.

2.2. Variation theory

Variation theory has emerged out of the phenomenographic tradition, mainly by the works of Lo and Marton (Lo, 2012; Marton, 2015). The concept formation of the theory is extensive and the presentation below is limited to the most essential concepts for this study.

Within the tenets of the theory rests the assumption that learning is the learning of something specific – the object of learning (Lo, 2012; Marton, 2015). The concepts patterns of variation, and critical aspects are essential in variation theory; in order to learn something, we need to experience that something in a new way. According to VT principles we need another thing to compare it with – we need variation in the learning situation. Regarding most objects of learning there are a great number of aspects the learner has to discern. The teacher's task is to define these aspects and identify the aspects which are critical for the learner's progression. The difficulties the learner encounters are called critical aspects and variation is the main key to support the learner, according to variation theory. By trying to single out a critical aspect the teacher can help the learner discern the aspect – something called separation. In a teaching situation the teacher is advised to vary the critical aspect by a pattern of variation called contrast, whereas the other aspects should be kept invariant (Marton, 2015). The idea is that it is easier for the learner to discern the critical aspect if it is only the critical aspect which is manifested in different dimensions of variation. By the variation, the critical aspect is brought to the forefront against a backdrop which to the highest extent is kept constant.

2.3. CAVTA in teaching

The close interaction between the teacher and the student has been emphasized as important in variation theory (Marton, 2015). One of the major findings of CAVTA in welding education

(Kilbrink et al., 2022) has been how tools from conversation analysis can help teachers improve their teaching in interaction, thus making use of the students' verbally and embodied displayed understanding to modify the teaching and learning situation. Including ways to enable interaction already in the planning, supports the teacher to be prepared to identify critical aspects. If there is an orientation towards a shared understanding and the students show signs of mastering the targeted critical feature, the correct value of a critical aspect, the students are ready to move on in their learning process.

In order to fully utilize the potential of the interaction, the teacher needs to be diligent planning and designing the teaching. The object of learning needs to be specified, and expected critical aspects need to be separated (Kilbrink et al., 2022). The visualization of critical aspects has been emphasized as important in the variation theoretic tradition (Pang & Ki, 2016; Thorsten, 2019). In the planning stage the teacher is therefore recommended to be creative finding suitable designs of exercises so that the students are supported in the discernment of critical aspects.

2.4. The learning study – three cycles of MIG/MAG welding education

The cyclic design of the learning study model (Marton & Runesson, 2015; Wood, 2014) is strongly intertwined with CAVTA, which concepts and theoretical tools permeate the complete teaching and learning process. Since the students display their skills and the way they understand the object of learning in the design of the teaching sessions of this study, there is no need for the pre- and posttests of a traditional learning study (Kilbrink et al., 2022). The cycles started with planning meetings, continued with teaching sessions and ended with evaluation meetings. The meetings were audio recorded and the teaching sessions were video recorded. The initial analyses were conducted throughout the learning study process, in co-operation between the researchers and the welding teachers. The integration of CAVTA principles and signs that learning took place was the focus of the analyses. The analyses served to further improve the integration of CAVTA into the teaching sessions. After the three cycles of the learning study had been conducted a process of selecting and transcribing relevant sequences from the empiric material followed. Sequences which exemplify the impact of CAVTA were transcribed and analyzed according to conversation analytic principles. In this paper the transcription has been translated into English.

The empiric material of the third year consists of two hours and 42 minutes video recorded material from three teaching sessions and two hours and 52 minutes audio recorded material from researcher and teacher team meetings. The selection of students was purposive. Four students, aged 16-18, who had not been taught in the welding method MIG/MAG previously, participated in each cycle, and accordingly, the four students were substituted for the following cycle. Ethical issues were taken into regard and addressed according to the guidelines of the Swedish Research Council (Vetenskapsrådet, 2002; 2017). This paper gives a brief overview of the complete process, and gives space to a clarifying example of the use of CAVTA in an actual teaching and learning situation.

In the syllabuses of welding education at Swedish upper-secondary schools the text describing the contents of practical welding is vague. Thus, the individual teachers are handed the responsibility to select the contents and design the practical welding education. In the first meeting of the three cycles, the welding teachers made the decision that the object of learning would deal with the welding method MIG/MAG. According to the learning study tradition (Marton & Runesson, 2015) and variation theory (Lo, 2012), the object of learning in a learning study ought to be something that students generally experience difficulties with, or something that the teachers have found problematic to teach (Carlgren, 2018). The teachers agreed that the settings of the equipment regarding MIG/MAG welding pose difficulties for many students and that the settings ought to be addressed early in the learning process of MIG/MAG welding. Thus, the object of learning was specified as the settings of MIG/MAG welding, in 3 mm, low alloy construction steel, in the welding position PA.

Preparation and planning the integration of CAVTA principles followed. Expected critical aspects (Kilbrink et al., 2022) were defined and ways of visualizing these through separation and contrast were discussed. How to keep other aspects constant was also discussed, since that is an essential recommendation of variation theory (Marton, 2015). Although the sound of welding is not mentioned at all in the syllabus of the course, the teachers agreed on including sound as subject specific contents when teaching the settings of MIG/MAG welding.

3. ANALYSIS AND RESULTS

Throughout the three cycles, the empiric material shows how the teacher team and the individual teacher continuously revise the teaching. They develop and redesign exercises in order to support the discernment of expected critical aspects. The teacher enacting the teaching sessions improves the interaction with the students and makes use of different semiotic resources in letting the students display their understanding. The narrow object of learning is the focus, but the dynamic nature of it (Lo, 2012) can be observed. For example, the teachers realize that the sound should be brought to the foreground to an even higher degree than they expected from the beginning. A more extensive presentation of the complete process has already been published (Axelsson et al., 2023). In the following we will concentrate on an analysis of a clarifying example of how the teacher was supported by CAVTA.

The example is an excerpt from the teaching session of cycle 2 (see Figure 1). In the excerpt, a student (S) is welding individually (see Figure 2). Simultaneously, the teacher (T) adjusts one of the settings, the wire speed. Preceding this excerpt, the teacher had demonstrated the adjustment of the wire speed in a gathering with the rest of the students, presenting 'a reference sound', the sound of the welding when the settings are correct. He had contrasted this correct sound with the sound of the welding when the wire speed was too low and too fast. The setting of the wire speed has a correlation with the setting of the voltage, but the teacher had decided to adjust only the wire speed in order to help the students discern that aspect of setting the equipment correctly.

Figure 1.
Teaching session (a modified video screenshot)

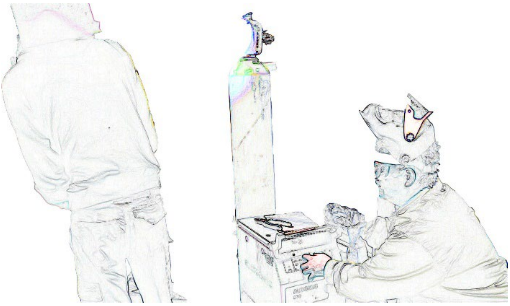

Figure 2.
Transcript 1

((the welding begins (4.0) – the sound is hissing, mixed with irregular popping sounds))
T: more wire (.) or less?
((S turns his head towards T, but continues welding))
S: more
T: more
((S is welding (4.0), while T slowly turns the knob controlling the wire speed, the sound changes towards a much more regular and sizzling sound))
S: and more
T: more?
S: yes:
((S nods and continues welding (5.5) the continous change in the sound towards the regular sizzling sound is simultaneous with T's increase of the wire speed))
S: more
T: more
((S is welding (3.5), T slowly continues adjusting the wire speed, and the the sizzling sound becomes even more regular))
S: more
((S continues welding (4.5), T still turns the knob which raises the wire speed and the frequency of the short circuits which cause the sizzling sound is much higher than at the beginning of the welding))
S: more
((14 seconds excluded from the excerpt))
S: yes, that's about it, then
T: yes, you can stop, then

During the first four seconds of the excerpt (line 1) nothing is said, but S starts to weld. By posing the question ”more wire or less?”, in line 2, T shows he wants information regarding the wire speed from the student. In line 3, S confirms he has noticed T's question, when he in the midst of the welding turns his head towards T. S then stresses the answer ”more” (line 4), thus displaying he wishes T to increase the wire speed. T responses by a confirming ”more”, in line 5. Then (line 6), T raises the wire speed and the sound changes to a more regular sizzling sound. S simultaneously continues to weld for four seconds and then utters ”and more” (line 8); an utterance T seeks to confirm by the question ”more?”, in line 9. S confirms T's question, in line 10, and reinforces the confirmation by nodding his head (line 11), still keeping his gaze at the welding he performs. In line 13, S demands higher wire speed which is confirmed by T repeating ”more” (line 14), whereupon he increases the wire speed (line 15). When S demands more (higher wire speed), in the lines 17 and 21, we can see that T no longer replies S verbally, instead he just responds to the demand by carefully and slowly adjusting the setting of the wire speed (line 18). In line 23, S shows his satisfaction with the settings, thereby displaying his understanding of the wire speed setting.

In the excerpt, the intervention of CAVTA includes that the already narrow object of learning, in this case the settings of the MIG/MAG equipment, has been decomposed even further into the expected critical aspect adjustment of the wire speed. This expected critical aspect is visualized by the pattern of variation called contrast (more or less wire speed), by letting the wire speed adjustment be the only aspect to be varied. Thus, according to the tenets of variation theory (Lo, 2012), the learner is supported in discerning the varied aspect. The variation of a critical aspect against a backdrop of other invariant aspects brings it to the forefront. The visualizing of the expected critical aspect occurs at the same time that the teacher encourages interaction by letting the student display his understanding of the object of learning. Thereby, the teacher can pay attention to whether or not there is an ongoing orientation towards a shared understanding. In this interaction, and the analysis of it, the use of conversation analytic procedure displays how the participants use different semiotic resources and different artefacts to create meaning in their orientation towards a shared understanding. Apart from the verbal language, the excerpt displays how head movements, sound, and different parts of the equipment are important in the process of establishing a shared understanding regarding the settings of the MIG/MAG equipment. Furthermore, in the continuing sequence of this excerpt the teacher and the student engage in a dialogue evaluating the exercise. In that interaction the sound of the welding is focused when the teacher and the student, using verbal language and gestures, try to agree on the targeted critical feature. In conversation analytic terminology, they negotiate in an orientation towards a shared understanding.

4. DISCUSSION AND CONCLUSION

In this study, we can see how CAVTA concepts such as separation and contrast in combination with an active ambition to enhance interaction in the pedagogic approach seem to support teachers when designing and enacting teaching and learning situations regarding practical objects of learning in welding.

The intertwined combination of conversation analytic and variation theoretic perspectives seems to help the teacher probing into the students' learning progression, thus supporting the teacher to revise the teaching. The combined focus of the learning contents, and the focus on the students' displayed understanding, when the expected critical aspects are being dealt with in the practical welding, is useful. The teaching and learning situations provide the teacher with helpful information in what way to proceed in the teaching and learning process.

In an ideal learning environment, these issues are dealt with in full-blown learning studies. The rich toolbox of CAVTA is probably best used with rich empiric data such as video recorded teaching sessions. Full-blown learning studies may be difficult to organize and to get means to, though. Nevertheless, CAVTA may also function as a more general approach for welding teachers. Paying extra attention to a narrow object of learning and a focus of variation in demonstrations in combination with a focus of how to interact with the students when designing teaching and learning situations, may serve to improve the practical welding education.

5. FURTHER RESEARCH

Results from this project could be relevant for other teaching areas including practical objects of learning. The importance of studying teaching and learning processes in relation to technical vocational objects of learning as a response to the lack of research in this area has been emphasized (Kilbrink et al., 2022). Therefore, based on the results from this study on welding, we have launched a new project, *Approaches to subject-specific teaching in vocational education*[2]*,* in collaboration with teachers from other technical vocational programs and aim to further study and develop teaching in different vocational subject-specific areas. In the next step we will focus on the uniqueness of each subject and on aspects that could be similar when dealing with practical objects of learning within different areas, with the purpose of developing vocational teaching and learning on a scientific basis.

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The Impact of Teacher Preferences in Learning by Evaluating

Scott R. Bartholomew, Brigham Young University, scottbartholomew@byu.edu
Emerson Barnum, Brigham Young University, emersongrace2002@gmail.com
Andrew Jackson, University of Georgia, andrewjackson@uga.edu
Nathan Mentzer, Purdue University, nmentzer@purdue.edu
Jessica Allen, Brigham Young University

ABSTRACT

Peer review and the evaluation of samples are common tools used in education and our research has shown positive impacts on student learning through the intentional evaluation of samples as a priming exercise—an experience we have termed "Learning by Evaluating (LbE)." While previous work in design and technology (D&T) classrooms with LbE has demonstrated positive student learning gains, we have not yet investigated the impact of the classroom teacher on the LbE experience for students. Therefore, our research sought to analyze the impact of a classroom teacher on student experience within a LbE experience situated in a D&T classroom. To better understand the impact the teacher has during LbE, multiple D&T classrooms engaged in LbE sessions were enrolled in this study. Each D&T classroom followed a similar protocol which had students engaged in an open-ended design problem who used LbE to evaluate samples of related work as part of their designing process. Specifically, we collected data from student LbE decisions to explore if students in different D&T classes valued different elements of the samples (e.g., did students in one class focus on aesthetics while students in another emphasized brevity in explanations). An online software platform (RMCompare) was used to engage students in LbE and collect both the quantitative data associated with the ranked preferences of the students and the qualitative data from their justifications for their selections. All students were enrolled in the same district-level course and presented with the same samples. Key findings—both similarities and differences—between classes will be shared in alignment with implications for design and technology classrooms.

Keywords: Adaptive Comparative judgment, Learning by Evaluating, Teacher Impact

1. INTRODUCTION

Research and investigation around the potential to use assessment and evaluation as a learning activity has led to a growing body of evidence (Bartholomew, Mentzer, Jones, Sherman, & Baniya, 2020) around the idea that students can learn by evaluating (LbE). For example, K-12 (Bartholomew & Yoshikawa-Ruesch, 2018) and university students (Bartholomew &

Yoshikawa-Ruesch, 2018) have engaged in LbE—typically facilitated by an online software and process called adaptive comparative judgment—with positive learning gains and improvements to the overall design process. In LbE the act of evaluation is situated near the beginning of a learning cycle (e.g., the design process) and used as a primer for students' later experience and work. Whereas traditional classroom approaches typically place evaluation at the conclusion of an assignment (with teachers as the evaluators), LbE places it at the forefront and engages students in the process of the evaluation.

Lacking in the present research around LbE is an exploration of the impact, if any, different teachers have on student experience when doing LbE (Bartholomew & Jones, 2020). For example, is it possible that differences in teacher style, classroom management practices, etc. may impact the way students engage in LbE? Further, how do these differences shape the student learning and experience? Given the rise in the use of LbE, and the positive findings for student learning, it is important to explore these ideas and the ways teachers may, or may not, influence the LbE experience. Our stated research question was:

> How are student LbE experiences similar, or different, as a result of classroom-teacher differences?

2. LITERATURE REVIEW

Although not required, LbE to date has largely been facilitated as part of a larger adaptive comparative judgment (ACJ) experience for students (Bartholomew & Jones, 2020). Therefore, a correct understanding of the current research into LbE will not be complete without a basic review of ACJ, its theoretical basis, and the way LbE is facilitated through ACJ.

2.1. Adaptive Comparative Judgment

ACJ is an approach to assessing the quality of items through comparison rather than subjective judgment, value or point-based allocation, or traditional rubrics (Kimbell, 2021). In an ACJ setting, an individual—or group of individuals—views pairs of items (e.g., design journals, product pitches, essays, interviews, etc.) and selects which item—of those displayed—they believe better satisfies a predetermined criterion. Following each selection, a new pair of items is displayed (which may or may not include one of the items previously displayed), and another comparative decision is made. These comparative decisions (a.k.a. judgments) are made until a rank order of all items is created – often with very high levels of reliability (Bartholomew & Jones, 2020). In addition to the rank order, parameter values can be generated as part of the process—parameter values differ from the rank in that they show both a magnitude and direction (e.g., ranks are all equidistant but parameter values denote both the direction of change and the magnitude/size of that change); these values are influenced by Rasch-modelling misfit statistics (see Pollitt, 2004 for a full discussion of parameter values). Finally, judge rationale for decisions are often collected as part of the comparative process through an automated software or other means.

Originally, ACJ was put forth as an alternative to traditional approaches to assessment which could be time-consuming and highly unreliable (Bartholomew, Strimel, Zhang, & Homan, 2018). However, research has shown that when students use ACJ as a learning primer (rather than a teacher using ACJ for assessment of student work), student learning is positively impacted (Mentzer, Lee, & Bartholomew, 2021). Further, research has shown high reliability levels even between student and teacher judgments (Baniya et al. 2019, Bramley 2015), an "easier" assessment process (Kimbell, 2021), and applicability in facilitating feedback from multiple assessors (Bartholomew and Yoshikawa 2018; Kimbell 2012b).

2.2. Learning by Evaluating

In 2020 Bartholomew, Mentzer, Jones, & Sherman coined the acronym "LbE" to describe the process of students viewing and evaluating examples of work using Adaptive Comparative Judgment (ACJ) prior to engaging in similar assignments themselves. Their work built on previous research into student ACJ for learning (Baniya et al. 2019; Bartholomew and Strimel 2019; Bartholomew et al. 2018a; Bartholomew et al. 2018b; & Seery and Canty 2017). Student comments about LbE have highlighted its ability to help them gain confidence (Canty 2012) and improve their own work (Bartholomew et al. 2019) as benefits of using LbE in the classroom. LbE has been used in various fields including Design, English, Engineering, and Business (see Bartholomew & Jones, 2020).

2.3. Teacher impact on student experience

Traditionally, LbE (and ACJ) research has not explored the similarities and/or differences in student experience based on class and/or teacher; rather, these studies have focused largely on treatment-level conditions (control or treatment group)—students who engaged in LbE and those that did not. However, academic studies have consistently shown that the teacher has the single biggest impact on student learning over any other variable (Hattie, 2015; Rockoff, 2004). This has held true despite differences in lessons, unit, school, location, and a variety of other factors (Hattie, 2017). As Fountas & Pinnell (2023, n.d.) note:

> Though a teacher may lean on a lesson to deliver instruction, the teacher is always the most critical factor in determining what a child can achieve in the classroom. No lesson plan or program will singlehandedly identify and impact a child's achievement and progress. No matter how well a teacher plans and structures learning tasks, it is the teacher's ability to make different decisions for different students at different times that informs the power and effectiveness of the instruction. The moment-to-moment instructional decisions teachers make based on their observations and analysis of children's learning behaviors are significant. The teacher teaches the child, not the book or program.

3. METHODOLOGY

To explore the potential impact of classroom teachers on student LbE experience, we enrolled teachers and students in five different technology & engineering classrooms in our study following IRB approval and collection of consent documents. Specifically, this research was conducted as part of a larger *National Science Foundation* grant (Award: 2101235) project between Purdue University, Brigham Young University, the University of Georgia, the International Technology & Engineering Education Association, and the Dekalb County School District in the greater Atlanta, Georgia area (USA). Each of the enrolled teachers, and their students, were working in a district-level course, *Foundations of Technology*. While the classrooms, locations, and teachers were all varied by school, the overall course goals and LbE items compared by students were the same. Fully recognizing the presence of myriad confounding variables resulting from the different classrooms, locations, and teachers, we set out to better understand the ramifications of teacher differences on student experience through our research question using both quantitative and qualitative means.

3.1. Quantitative: ACJ session rank and parameter statistics

We created five ACJ sessions–each consisting of the same items for comparison–and enrolled consenting students in each of the participating classes in these sessions. While all items (N = 50) included in each session were identical, the items viewed by individual students were varied (because of the algorithm used by the ACJ software *RMCompare*). Further, teachers were given the freedom to craft individual holistic statements (i.e., the criterion provided to students with which to make judgments) and introduce and debrief the project however they deemed best. Students made between 5-10 comparisons of backpack images and, in each instance, selected the backpack design they thought best. Following all the judgments, the rank order (1-50) and parameter values for the items in each session were collected and compared using both Pearson and Spearman correlation coefficients for the parameter values and rank order, respectively. The resulting rank orders, parameter values, and correlation coefficients were used in the quantitative data analysis.

3.2. Qualitative: Analysis of student comments made during LbE and teacher interviews following the session

In addition to the five LbE sessions, and the accompanying quantitative data, we also collected student comments made while completing the LbE decisions. In each instance, students were prompted to justify their decision of one item over another. These comments were collected via the online ACJ platform *RMCompare.* Thematic coding techniques following recommendations from Saldaña (2013) were used to explore these comments in line with the research objective of exploring the potential for differences in student LbE experience based on different teachers. This process involved an initial review of the comments which was completed to identify potential themes. Multiple reviewers completed this step and themes were compared and refined following the review. After solidifying themes, a subsequent review of all comments was completed wherein thematic codes were applied to all student comparison comments.

These analyses of student comments were undertaken as a means of potentially triangulating the quantitative findings from the LbE sessions with the overall goal of investigating our stated research question: How are student LbE experiences similar, or different, as a result of classroom teacher differences?

4. RESULTS

Following the LbE sessions, and the collection of the associated data, the rank orders and parameter values for the items in each session were collected and conditioned prior to statistical analysis. Additionally, all thematic coding findings from the qualitative analysis of the student comments and teacher interviews were organized for sentiment and triangulation with quantitative findings.

4.1. Quantitative Findings.

Both a Spearman (rank) and a Pearson (parameter value) correlation were run for the results of each session (see Tables 1 and 2) and instances of statistical significance were noted at both the $p < .05$ and $p < .01$ levels.

Table 1.
Spearman Correlations for Rank Orders

	T2	T3	T4	T5
T1	.38**	.29*	.18	.29*
T2		.32*	.47**	.39**
T3			.34*	.29*
T4				.16

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table 2.
Pearson Correlations for Parameter Values

	T2	T3	T4	T5
T1	.37**	.27	.16	.28*
T2		.31*	.47**	.42**
T3			.29*	.27*
T4				.12

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Of note, the results from most of the correlations were statistically significant suggesting similar results from the LbE sessions run in different classrooms. This is not entirely surprising as similar course outcomes across classrooms should lead students to similar decisions in the comparative judgments between items.

More interesting to us were three instances of non-statistical significance in the correlations between the session results of several teachers (Teacher 1 and Teacher 3; Teacher 1 and Teacher 4; Teacher 4 and Teacher 5). Of these, the correlation between Teacher 1 and Teacher 3 approached significance (and was significant in the rank order) and no further investigation was conducted.

Building on the differences discovered through the lack of statistical significance in the LbE session rank and parameter value outcomes, the correlations between Teacher 1 and Teacher 4 as well as the correlation between Teacher 4 and Teacher 5 were investigated further. This exploration was conducted as part of the qualitative analysis reported in the next section.

4.2. Qualitative Findings

The process of manually coding qualitative data required the identification of recurring themes within interviews or other transcripts, followed by the systematic documentation of noteworthy discoveries. In the context of this qualitative research, this method of thematic coding was employed to analyze students' comments pertaining to their LbE decisions and revealed several similarities and differences between the student rationales for those students in classes taught by Teachers 1, 4, & 5.

4.2.1. Teacher 1

Teacher 1 is a male teacher with several years of experience teaching in the school, district, and with the course/curriculum. The criteria selected by Teacher 1 for students to use in making comparative decisions was: “Imagine you are redesigning a backpack. Which image is a more creative approach to research in the design process?”

Comments (n = 239) were mainly coded using the following categories: holding capacity (n=49/239), functionality (n=41/239), creativity (n=60/239), and comfort (n = 16/239). Specifically, Teacher 1’s students had comments centered on both the functionality of the backpack designs and the form (creativity) in these designs. This is an especially interesting finding given the holistic statement chosen by Teacher 1 which focused squarely on “which image is a more creative approach…” Example student comments around functionality include:

> “This would help because my phone could be dying and I could be on the go and I can charge my phone on the go.”
>
> “I chose option B because not many people have kids, but everyone can use a backpack at some point. Also, many people would problem like the design on option B a lot more.”
>
> “I chose this because even though the camping and hiking bookbag can be put to use really well, I feel like the stroller can be put to use more efficiently.”

Additionally, other student comments centered on the creativity of the backpacks shown. For example, one student remarked:

> "Option B is very creative because they created their own backpacks out of different materials. It is also most likely handmade."

Overall, a notable feature of the comments from Teacher 1’s class was the specificity of answers; while many student comments indicated a feature of the backpack (that was either included or not), the students in Teacher 1’s class did so with more detail than those in other classes.

4.2.2. Teacher 4

Teacher 4 is a female teacher with many years of experience—both in teaching the class and in the school/district. The holistic statement chosen by this teacher was: "Which carrying approach is most usable and why?"

Not surprisingly, the comments (n = 301) from her students were most inclined to designs that were practical and usable—in line with the stated holistic statement—and this was the most common code for their responses (74/301). Additionally, Teacher 4's students were the only ones to occasionally point out flaws in the option they did not choose (as opposed to simply indicating positive qualities of the option they chose), though these still largely centered on reasons related to functionality. Example comments from Teacher 4's students included:

> "Option B is clearly better than A. This is because it is more complex and useful, you can even charge your phone."

> "Option B is more usable because you could take it around wherever you need it. Unlike a carrier on a bike, you cannot take that everywhere."

> "There are more compartments for different things to stay more organized and it takes less work trying to carry it or keep it on."

4.2.3. Teacher 5

Finally, Teacher 5 is an experienced female teacher with similar years of experience to Teachers 1 and 4. Teacher 5 used the same holistic statement as Teacher 1 ("Imagine you are redesigning a backpack. Which image is a more creative approach to research in the design process?") but the analysis revealed that Teacher 5's students placed a higher value on self-expression (e.g., form) over functionality and practicality. Comments from students in Teacher 5's class (n = 207) fell into categories of creativity (n=45/207), appearance (n=20/207), and uniqueness (n=19/207). Overall, Teacher 5's students did not shy away from preferring more innovative designs, and, of the three classes reviewed here, these students placed a much bigger emphasis on creativity and individuality. For example, some students commented:

> "The lion is a very creative back pack as opposed to a normal backpack that is used often."

> "I like the way the backpack looks, and its aesthetic value is above the other."

> "It is a very different design than most backpacks and seems like it could hold more."

5. DISCUSSION

Our observations of LbE implementation across different classrooms suggested that teacher differences in style, implementation, and facilitation may impact the experience of students as they engage in LbE. However, existing research into this idea was lacking (Bartholomew &

Jones, 2020); therefore, our intent in this research was to explore the potential differences in student LbE experience based on their different teachers. This was a natural extension of other work around ACJ (Bartholomew, Strimel, & Jackson, 2018; Bartholomew, Strimel, & Yoshikawa, 2019) and LbE (Bartholomew & Yauney, 2022; Bartholomew et al., 2020; Bartholomew, Ruesch, Hartell, & Strimel, 2020; Mentzer, Lee, & Bartholomew, 2021) which has demonstrated the potential for this approach to improve student performance but has not investigated the specific nuances of *how* LbE should be implemented to be most effective. Therefore, we engaged students across several different classroom in the same LbE session and explored the potential similarities and differences in their experience (e.g., their judgments and their comments made while comparing items).

Importantly, we did not attempt to assess the "accuracy" of student judgments (e.g., how well aligned their rank orders are with those of professionals or an established rubric) in these settings or the final results of the rank order or parameter values from each session; rather, we have taken the ranks produced by students and investigated how they related to one another to examine the consistency across students enrolled in different classrooms. This exploratory research, while informative, also does not explain *why* such results were obtained and we readily admit the presence of a variety of external factors that likely influenced the findings (e.g., school, teacher, schedule, classroom, neighborhood, and a host of other differences). We do note that all participating students were enrolled in the same course in the same district in the same state in the United States. Further, the set of items viewed by the students was identical; however, as can be seen from both the quantitative and qualitative analyses performed, there were distinct differences in both the items selected by students (by class) and their rationale for selecting one item over another. Importantly, we did not dictate to the teachers the holistic statement (or judgment criteria) they should use with their students; this was left to the teachers to decide. While student comments for both Teacher 1 and Teacher 4 seemed to align well with the chosen teacher criteria for judgment seen in the holistic statement (either emphasizing form or function), students in Teacher 5's class emphasized form even though the holistic statement was specifically centered on function.

While the differences in student comments made sense—and we hypothesized that potential differences would exist—it was both interesting and insightful for us, as researchers, to unearth these differences. While the quantitative analysis revealed a difference (i.e., instances of non-significant correlation between rank order results), this analysis did not reveal why such a difference existed. Later qualitative analysis showed an emphasis on either a) practicality/usefulness (a.k.a. function) or b) individuality/creativity (a.k.a. form). A difference that was often aligned with the specific holistic statement crafted by the teacher.

The criteria of both form and function appeared across all classrooms (e.g., see the high levels of reliability in rank orders produced between classes), but there were differences in the rank orders produced by the students with Teachers 1, 4, and 5. Specifically, the qualitative analysis showed that while Teacher 1 and 5's students' comments were more focused on function, Teacher 4's students' comments emphasized form.

These differences align with those found in other design research which shows that the criterion for success is often divided between form and function (Khan, Pitts, & Williams, 2016). For example, Bartholomew, Reusch, Hartell, & Strimel, (2020) compared ACJ sessions completed by assessors in different countries and found that an emphasis on either form or function was one degree of separation in the results between countries. Interestingly, while all students/teachers in this project were in the same country, state, and district, the debate between form and function remained and the consensus produced in each classroom differed.

Additional research is needed to parse out the *why* behind these findings, as well as the *what now?* With respect to the inception of these judgments, it may be possible to uncover how different cultures created in each class have contributed to differing student mindsets in LbE. More closely reviewing the course-level objectives (e.g., how do form and function fit into the course-level objectives) may be relevant to understand how various types of judgment are expected in the course. Perhaps the teachers' educational and professional background and their design pedagogical knowledge also play a role here. Further interviews with the teacher about their intentions in these LbE sessions and when teaching design, in general, may reveal sources of influence in students' judgment.

Then, we wonder if students' judgment differences and rationale translate into later action (e.g., if they focus on form during LbE, do they maintain focus on form while designing?) and what other ramifications (academic or otherwise) their different experiences in LbE have. Further research recommendations here include longer observations of student design work or interviews, and a more detailed scripting of the LbE experience (e.g., the introduction made by teachers as well as the debrief following LbE).

Recognizing that our findings are specific in setting and narrow in scope (e.g., the students enrolled in this study, their classes, teachers, schools, and district), we nevertheless recgonize potential applications for our findings to other settings. In addition to our recommendations around the need for further research into LbE and teacher impact, we recommend teachers 1) recognize and 2) be intentional about their own use of LbE in the classroom with attention to the wording of the holistic statement for comparative judgments. For example, if *form* is more important than *function* for a given design task, the teacher should emphasize and teach the principles of form prior to, and as a part of, both the LbE and overall design experiences. Further, the wording of the holistic judgment statement should intentionally align with the desired outcomes of the teacher. Alternatively, if both *form* and *function* are to be equally valued, teachers must recognize the ways they may, or may not, be influencing students' perceptions of these criteria—in both their classroom discussions and the provided rationale for comparisons.

Teachers interested in using LbE may consider ways different items (i.e., viewed by students) or holistic statements (i.e., judgment criteria for selecting between items) could impact the learning in their classroom. We note that design classrooms often employ gallery walks and other comparative activities (Rodenbaugh, 2015); these activities may be improved the use of targeted questioning around *form* or *function* with a specific emphasis on principles, ideas, and skills a teacher wishes students to identify or hone in on. Additionally, classes outside of the Design and Technology area may similarly benefit from engaging students in LbE activities; especially if an intentional emphasis is placed on various aspects (e.g., form vs. function) of an assignment or task.

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The Impact of an Integrated Literacy and Design Activity on Student Attitudes Toward Coding

Scott R. Bartholomew, Brigham Young University, scottbartholomew@byu.edu
Emerson Barnum, Brigham Young University, emersongrace2002@gmail.com
Jessica Allen, Brigham Young University
Kellie Wilcock, Brigham Young University, kellieluellawilcock@gmail.com

ABSTRACT

Coding is a growing and important area within Design and Technology Education and is also one of the arenas of education where the most significant effort is being given to increase diversity, equity, and inclusion. To introduce young learners to coding and engineering design, a pioneering curricular unit was designed for upper elementary schools, intertwining literacy within its framework. To reasonably fit in the already overcrowded standards for elementary schools in the United States, the integration of multiple subjects was a defining feature of this unit which we termed "Digital Storyboards." Digital Storyboards integrate engineering design, literacy, and coding into one unit which emphasizes students' ability to design, develop, and automate an illustration from a favorite story using a variety of electronic elements including LEDs, copper tape, and micro:bits. Students are intentionally taught core content from literacy (the elements of a story), engineering (design), and computational thinking (variables, loops, Booleans) while they create and program their own digital storyboards as part of a 10-week unit in class. While initial implementations of digital storyboards in one classroom positively impacted all students, a more significant impact was discovered with female students specifically – an important idea since females are traditionally underrepresented in coding. Following our pilot work, the digital storyboard project was expanded into 16 classrooms with more than 200 students. Our findings, as well as the practical implications for teachers engaged with elementary and secondary content related to literacy, engineering, design, and computer science, will be shared.

Keywords: Elementary Education, Coding Integration, Computer Science Education, Literacy Integration, Electrical Engineering Education

1. INTRODUCTION

In the predicted future, individuals who are deemed literate within society will require, at minimum, a foundational comprehension of programming skills. Undoubtedly, the need for this essential skill will significantly increase, particularly in the context of childhood education (Murphy, 2022). Prensky (2008), argues that as "programming becomes more important, it will leave the back room and become a key skill and attribute of our top intellectual and social classes, just as reading and writing did in the past".

As programming literacy increasingly emerges as a prerequisite for surviving the digital world, the imperative to develop programming skills in the current generation of elementary children becomes ever more relevant (Murphy, 2022). However, the integration of coding basics into schools in the US is a daunting task, particularly when considering the extensive teacher training required and the demanding curricular standards upheld by American educational institutions (Yadav, Gretter, Hambrysch, & Sands, 2016).

Extensive research has illuminated the reciprocal relationship between computer science and literacy, underscoring the advantages of integrating computer science lessons with literacy instruction (Jacob & Warschauer, 2018). Programming has the potential to support literacy skills by encompassing writing, reading, brainstorming, and much more (Murphy, 2022). By occasionally merging these territories, elementary schools may be able to effectively address the vital incorporation of computer science while also tackling the demanding requirements of educational standards and schedules.

1.1. Digital Storyboards

The Digital Storytelling Project (DSP) was devised to integrate coding skills, literacy, and engineering design. To facilitate implementation within the busy schedules of the elementary school teachers, undergraduate Design and Technology Education students were sent to team-teach with elementary school teachers in several classrooms. These visits occurred once a week for a duration of ten weeks. Research data were gathered through the administration of pre- and post-program surveys, as well as interviews conducted with both students and teachers following the conclusion of the project.

Throughout the course of the 10-week program, the students were guided in the exploration of fundamental concepts in literature, which were then enriched through the integration of coding and engineering principles. In the initial weeks, the students received instruction on the essentials of storytelling, practicing familiar vocabulary and retelling narratives as a preliminary review before delving into more advanced lessons. Subsequent weeks were dedicated to lessons on circuitry, computational thinking, and the main aspects of storytelling. This paved the way for the introduction of a Digital Storyboard, a project that aimed to merge engineering design, literacy, and coding. This activity offered a vast range of creative possibilities, allowing each student to select a board that features a scene from a favorite TV show or movie that they then personalized through coloring, coding, and programming of LED lights. The circuitry component proved challenging for many students, yet it emerged as a highlight of the DSP according to subsequent interviews. In the final weeks of the project, the students were further introduced to the capabilities of micro:bits, engaging in coding challenges and projects designed to encourage creativity, brainstorming, and problem-solving abilities.

The specific research question guiding our investigation was: What is the impact, if any, on student perceptions of coding, following participation in the Digital Storyboard Project?

2. LITERATURE REVIEW

The Digital Storytelling Project follows both the Utah (a rocky mountain state in the United States of America) state *Science with Engineering Education* (SEED) and *English Language Arts* (ELA) standards. While literacy, encompassing the skills of reading, writing, verbal expression, and critical thinking, has long been recognized as a fundamental pillar in the educational curriculum (Billman & Pearson, 2013), we noted that the instruction of engineering design and computational thinking can be effectively intertwined. Specifically, the context of engineering design presented a fitting opportunity for children to actively engage in computational thinking while they simultaneously engaged in this literacy learning experience (Ehsan, Rehmat, & Cardella, 2021).

2.1. Literacy

The early stages of childhood play a crucial role in equipping young learners with the essential skills for adult literacy (Hopkins, Brookes, & Green, 2013). Research shows that during this foundational phase, it is imperative to pose significant questions and emphasize literacy competencies such as phonological awareness, phonics, fluency, and reading comprehension (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Often, these literacy competencies can be taught through technological tools, supports, and experiences (Hopkins, Brookes, & Green, 2013).

The initial lessons of the DSP focused on the fundamental elements of storytelling embedded in the literacy standards; these included characters (CCSS.ELA-LITERACY.RI.4.6), plots (CCSS.ELA-LITERACY.RI.4.5), themes (CCSS.ELA-LITERACY.RI.4.2), and settings (CCSS.ELA-LITERACY.RI.4.3). Over the course of the ten-week program, students were encouraged to integrate their newfound skills with their storytelling abilities. The digital storyboards provided an opportunity for students to bring these stories "to life." Drawing upon their literary knowledge, they worked to build up their narratives to the climax of the story, where they then unveiled their boards to their classmates and used these boards as a means of telling their chosen story in a new and exciting way. At this pivotal moment, students illuminated their boards. Some incorporated personalized micro:bit codes to enhance the uniqueness of their storyboards. For instance, they programmed flashing lights to act in place of laser shots from their Star Wars ships, adding an extra layer of creativity. While literacy education represents an immensely large area of research, additional focus in not devoted to the particular elements used as engineering and computational thinking were the topics of main interest.

2.2. Engineering Design

Engineering is seen as beneficial for both student development and success along with workforce readiness; thus, leading to its integration across K-12 schools (Arik & Topcu, 2020). This has resulted in the development of numerous endeavors, research projects, and educational lessons and materials employing the "Engineering Design-Based Learning" method (Arik & Topcu, 2020). The incorporation of the engineering design process, encompassing the stages of asking, imagining, planning, creating, and improving (Syukri, Halim, Mohtar, & Soewarno, 2018), was emphasized throughout the lessons to equip the students with the proper tools to navigate the challenges associated with the DSP, particularly the micro:bit challenges. Research has shown engineering design can provide students with an opportunity to fail often and then succeed more quickly; thus, encouraging teachers to make the value of failure for learning and improving designs more evident in their lessons (Cunningham & Lachapelle, 2014). Engineering design activities can also encourage students to both reflect on their designs and ask new and better questions for improvement; therefore, encouraging students to embrace failure if they learn from those experiences and enhance their designs, learning, and ideas (Cunningham & Lachapelle, 2014). We intentionally combined literacy and computational thinking *through* an engineering design activity to leverage these opportunities for students.

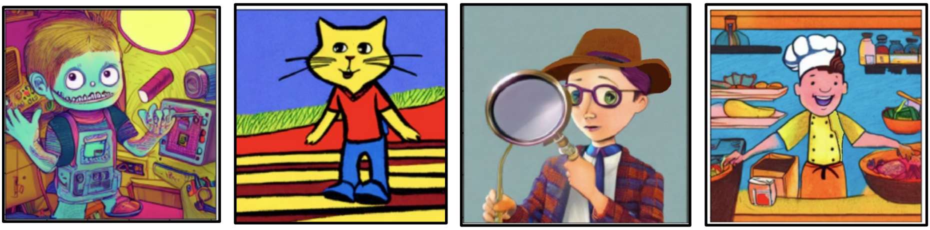
2.3. Computational Thinking

Computational thinking describes the several mental procedures involved in framing problems and devising solutions in a way that these challenges can be efficiently executed with the assistance of technology (Wing, 2011). The key components of computational thinking include decomposition, pattern recognition, abstraction, algorithmic design, and evaluation. While computational thinking is widely practiced in the world of computer programming, it is an important component of computer science education that is gradually integrating into the K-12 curricula to promote problem-solving skills and critical thinking among students (Wing, 2011). Additionally, the state of Utah (located in the United States) recently passed legislation mandating all elementary school teachers include computational thinking in their curriculum – another key element in our desire to include computational thinking in the Digital Storyboard Activity.

Our past experiences demonstrated some frustration and struggles as students were introduced to computational thinking principles. These struggles did not end with students and elementary school teachers were also often hesitant to embrace these ideas which were often new and foreign to them. Therefore, as part of the DSP, we relied on literature around character introduction. Specifically, Wand, Lee, & Chu (2010) who demonstrated that the probability of children grasping challenging concepts increases through the utilization of sensory stimuli such as vivid characters; thus, establishing connections that can unlock the potential of the developing brain. To enhance the comprehension of computational thinking, our strategic approach involved the creation of four distinct characters, each associated with a specific concept. These "computational thinking friends" (see Figure 1) were introduced across participating classrooms as part of the Digital Storyboards Project (DSP). While computational thinking is an umbrella term that has been used to refer to a variety of fundamental concepts and reasoning methods that originated in computer science, these students were introduced to decomposition, pattern recognition, abstraction, and algorithmic thinking in the context of four distince characters with personality traits mirroring the computational thinking principle they were named for.

Deco the Zombie served as a guide, emphasizing the significance of decomposition - the skill of breaking down complex problems into manageable steps. Pat the Cat highlighted the importance of recognizing patterns, emphasizing the value of examining past problems and solutions to inform current challenges. Abs the Detective encouraged students to think creatively, urging them to visualize abstract ideas and explore unconventional solutions. Lastly, Algordo the Chef guided students in the art of following and generating precise instructions, particularly when engaging with coding exercises involving Micro:bits.

Figure 1.
Computational Thinking Friends: Deco, Pat, Abs, & Al Gordo



By merging these characters with the core lessons of literacy, engineering design, and computational thinking, students were encouraged to integrate their knowledge in both literacy and technology, enabling them to automate sections of their storyboards. This process provided students with the opportunity to witness the physical completion of their digital storyboards.

3. METHODS

To gauge the impact, if any, of the DSP on student perceptions of coding, a mixed-methods approach was utilized which encompassed a pre/post survey as well as semi-structured interviews completed at the conclusion of the DSP. This approach was utilized to explore both the *what* (quantitative findings from the ESCAS; pre/post) and the *why* (semi-structured interviews) of the students DSP experience. Specifically, quantitative data collection came as students completed the Elementary Student Coding Attitudes Survey (ESCAS; Mason & Rich, 2020), a 23-item instrument that assesses elementary students' coding attitudes and self-efficacy before and after engaging in the DSP activities. All items are measured using a six-point Likert scale, where selecting a 'one' represents strong agreement with the statement and selecting a 'six' represents strong disagreement. The ESCAS was specifically designed to assist educators, administrators, and researchers in their attempts to better understand which factors influence students' attitudes toward coding and confirmatory factor analysis using data from 6000 4-6 grade students identified five strong factors: coding confidence, coding interest, social value, perceptions of coders, and coding utility (Mason & Rich, 2020).

Qualitative data collection came through semi-structured interviews conducted at the conclusion of the project. Following the DSP, five students from each class were interviewed by a member of the research team. These five students were selected by the teachers of the class. Teachers were asked to choose two top, two low, and one middle-performing students for the interviews – without letting the research team member know which category each student was aligned with. This quota sampling was used to ensure that a variety of student experiences were included. Interviews were conducted using semi-structured interviewing techniques from Berg (2009) and averaged between 5-10 minutes in length. Each interview was initially recorded and then later transcribed (interview questions are included in the Appendix).

Following the transcription of the interviews, all student responses were collated for further analysis by members of the research team. The first step in this process was for each member of the research team to read over the students' responses and develop initial thoughts and ideas regarding themes. A discussion was held following this exercise and several potential categories were established. Following this process, each member of the research team independently coded several student interviews using the proposed themes and, following this coding, a comparison of results and discussion was undertaken. This process was repeated three times with a refinement/replacement of codes until a final coding scheme was developed. This process served as an inter-rater reliability check as differences in coding were discussed at each stage until agreement was reached among members of the research team. Further, the addition, removal, and refinement of thematic code wording at each step also assisted in improving the reliability between members through discussion and improving understanding for each coder.

When a final coding scheme was developed, with no discrepancies in coding theme assignment between research team members, each student response was independently coded by multiple members of the research team using the final themes (see Table 1).

Table 2.
Themes for the qualitative thematic coding of student interview responses

Theme	
1	Grit
2	Reference to computational thinking characters
3	Coding Inputs and Outputs
4	Following Explicit instructions vs Problem Solving
5	Physical components versus digital components
6	Specific reference to a task/challenge
7	Teamwork
8	Choice/Freedom
9	Complexity of task/directions
10	Mentor/Adult influences

The resulting counts–both total and by thematic code–were later used in conjunction with the quantitative findings to both triangulate and explore the findings from the DSP experience for students.

4. FINDINGS

Two-tailed paired t-tests were used to determine if any statistically significant shifts were detected between the pre-tests and post-tests in each of the five categories measured by the ESCAS: Confidence, Interest, Utility, Social Influence, and Perception of Coders. The mean shift was found to be significantly positive in all categories with a p-value below .01 (See Figure 2 and 3). Figure 2 presents the mean numerical equivalent of all students' responses combined. For example, the mean pre-test score for most categories was between 2 and 3 meaning that students generally disagreed with the provided statements. The mean post-test scores for most categories were between 4 and 5 meaning that students generally agreed with the provided statements.

Figure 2.
Pre to Post Change in Students' Attitude for Coding (Likert scale 1-6 questionnaire)

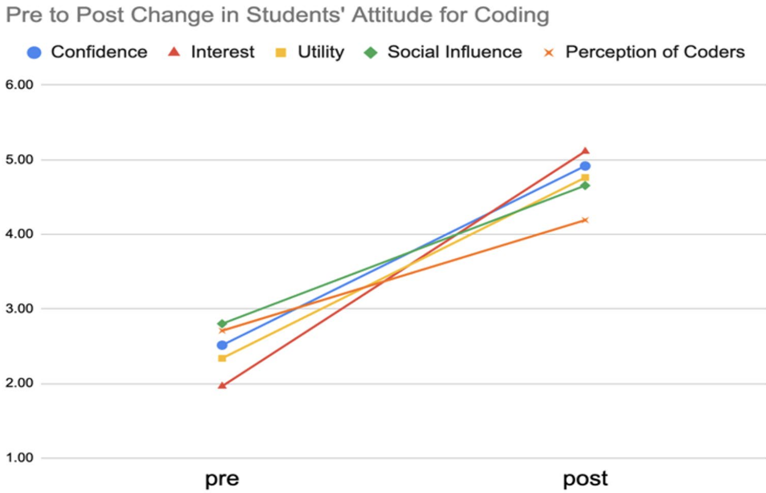
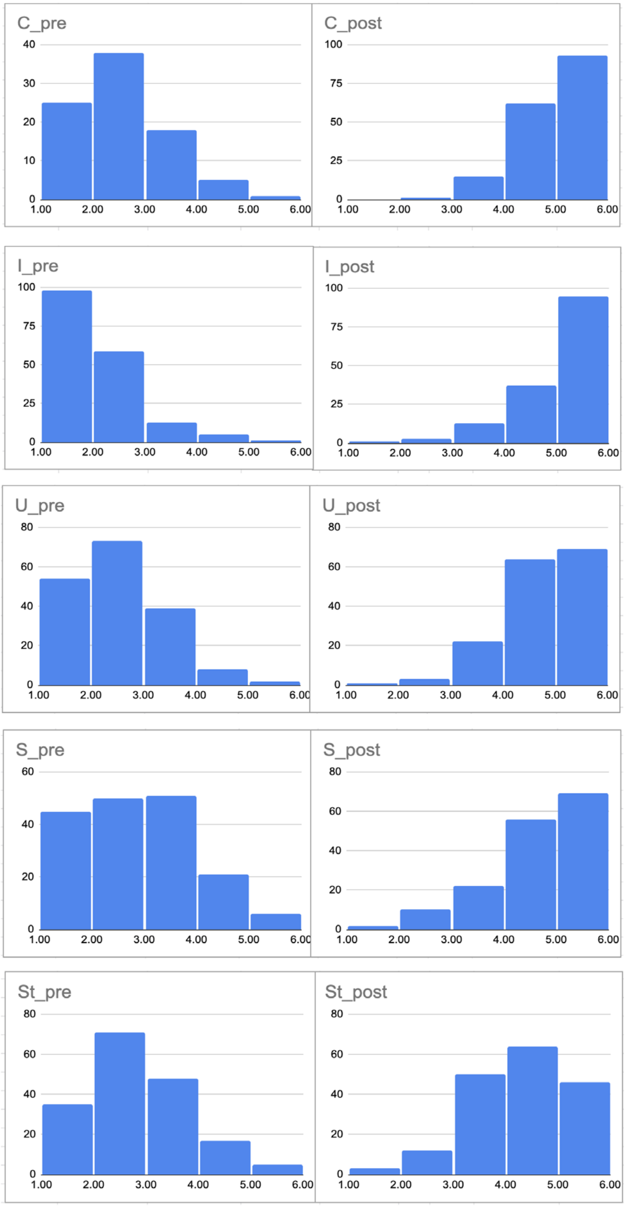


Figure 3 presents a histogram of each students' average response to each category on both the pre and post-tests. For example, in the category of confidence the most common average response was between 2 and 3. However, following students' participation in the DSP the most common average response in the same category was between 5 and 6. The right shifts of the histograms in each category show a shift towards greater agreement with the statements in the ESCAS (e.g., positive perceptions of and attitudes towards coding).

Figure 3.
Pre to Post Change in Student Attitude for Coding by Subarea



The independent coding of student interview responses by multiple members of the research team resulted in a total of 249 unique student statements being coded into one of the identified categories. The total counts, as well as the proportion for each theme, are included in Table 2.

Table 2.
Counts for thematic coding of student interview responses

	Theme	**Count**	**Percentage**
1	Grit	26	10%
2	Reference to computational thinking characters	22	9%
3	Coding Inputs and Outputs	2	1%
4	Following Explicit instructions vs Problem Solving	26	10%
5	Physical components versus digital components	26	10%
6	Specific reference to a task/challenge	92	37%
7	Teamwork	21	8%
8	Choice/Freedom	15	6%
9	Complexity of task/directions	7	3%
10	Mentor/Adult influences	12	5%

4.1. Student Interview Themes

While student responses to interview questions were spread relatively evenly across the identified thematic categories, it was noteworthy to the researchers that the most coded area was student comments about a specific task or challenge. Students often mentioned a challenge that was especially fun/exciting or difficult/frustrating. For example, one student referenced the traffic light challenge by saying:

> "Um I it was kind of hard because the um like it was kind of frustrating too because it like didn't turn on, (*) you get a little mad because like you've been working on it or maybe it like would turn on and off and on and off."

We also noted many instances of student comments that demonstrated an ability to do hard things, to push through a challenge, or to work harder than they had on other tasks - all areas we labeled as "grit." This idea of grit was not something we had originally hypothesized as an area arising from the study, but several student comments highlighted this as a benefit of student participation; for example, students commented:

> "It was so hard. And then we're like, this is too hard. I can't do it. And then we keep trying and trying and trying. And and then it's like, oh, it's finally working."

> "I liked how it was challenging because I had like no idea what I was doing, but it was fun when I was done because I thought I could maybe do that again."

> "·It was difficult. But later the as soon as I got towards the end it came together to me really easy. So now I can solve coding projects."

> "We got all the lights to turn on. I thought it was impossible. Because it was super hard for me but I got over it. That's what was most exciting."

Several students mentioned challenges, and successes, from both solving written instructions (e.g., those included in the tasks) and using open-ended problem-solving skills. Although we did not originally delineate between these types of problems, it was interesting to note student comments that alluded to these ideas, including:

> "So I learned about thinking for like how to do it in ways of like if mine didn't work"

> "Yeah, I learned that like … if something doesn't work, you can rethink and um rethink what happened and see and change that. See if that works. …"

> "So the paper is telling me to do this but I have to like, think how am I gonna do it?"

Finally, we noted several instances where students specifically referenced either the physical (e.g., LEDs, wires, breadboards) or digital components (e.g., code, CT characters). This was an interesting delineation as we did not intentionally separate ideas, concepts, or challenges into these categories. Student comments included:

> I really like the story card, because like, there was a little light that we had to figure out which side was negative and positive. And then also with their like, copper tape and stuff like that, and the drawing and the light and stuff, and the battery. And also the story. What I liked that a lot, because then we got to like, weave the lights through it and then hook a battery up to it.

> "...[the challenge we were working on] was kind of hard, because we had to like, hook it up to the computer and then we had to change it and then download it and change it and change it and take it and then download it again. And then also like putting the battery in and then the battery pack into the microchip to make it make it sound."

5. CONCLUSION

Arguments have been made in favor of implementing computational thinking and coding into STEM curricula within K-12 (Sengupta, Kinnebrew, Basu, Biswas, & Clark, 2013). Given this perspective, it is not unreasonable to anticipate a steady incorporation of computer science concepts into future programs, areas, and educational institutions. In many instances, the teachers tasked with incorporating these ideas are not prepared to do so – whether they be elementary school teachers or middle/high school Design & Technology teachers. By starting to prepare teachers for these imminent changes, we can ensure a more smooth and successful transition toward a curriculum that welcomes and prepares students for the demands of the near future.

The Digital Storyboards Project employs a distinctive method aimed at introducing students to engineering design and coding by intertwining it with literacy components – something that we anticipate being attractive and reasonable for currently-practicing Design & Technology teachers given their background and the implicit connections to other commonly-taught content. Further, the connections between the DSP and literacy principles should make it both attractive and feasible for elementary school teachers to incorporate. Preliminary data analysis indicates that the DSP has demonstrated promising results, leading to a favorable shift in the majority of students' perspectives toward both computer science and coders. The successful utilization of our unique approach of combining elements from several silos (literacy, engineering design, coding) into a single project also lends credence to the potential for additional activities which synthesize several areas, ideas, and courses.

However, to ensure success throughout K-12 schools, it is important to explore potential avenues for improvement that does not involve the additional support of undergraduate students. Ongoing research is being conducted, including the expansion of more 4th-grade classrooms and teachers. The hope of this future research is to enhance the DSP's effectiveness and sustainability, thereby proving its value as an innovative, sustainable, and positive educational initiative. Findings from these ongoing efforts can be used to continually shape and improve the usefulness of the approach as well as inform future efforts centered on combining various subjects/topics/fields into a cohesive project for students.

An aspiration for the future of this program is to integrate the Digital Storytelling Project (DSP) into classrooms – both statewide and nationwide. Specifically, our next efforts are focused on eliminating the dependency on undergraduate student teachers. This expansion would enable greater exposure to computer science, engineering design, and literacy for elementary-aged students. Additionally, our review of student semi-structured interview comments and survey results is inspiring adjustments to further improve the project efficacy.

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7. APPENDIX

Tell me about your experience with the Digital Storytelling project

(i) What did you like, dislike, etc.?
(ii) What was hard, easy, fun, exciting, challenging?
(iii) What did you learn about Computational Thinking while working on this project? Did your experience surprise you? Can you see yourself using this information again, how?
(iv) Can you identify any instances of problem decomposition from the activity?
(v) Can you identify any instances of pattern recognition from the activity?
(vi) Can you identify any instances of abstraction from the activity?
(vii) Can you identify any instances of algorithm design from the activity?
(viii) Would you consider a career in Computational Thinking after an experience like this?
(ix) Anything else you'd like to share with me from this experience with the Digital Storytelling Project?

Teaching Food Technology Through the Narrative of Food

HildaRuth Beaumont, Institute of Education UCL, hildaruthbeaumontt@btinternet.com

ABSTRACT

This paper takes the position that food technology may be taught in secondary schools (learners aged 11 – 16 years) by a consideration of the narrative of food in the world. This narrative starts with food production mainly through agriculture and moves on to include storage, preservation and processing, sales, and distribution at different levels of scale, complexity, and sophistication dependant on context and concludes with food preparation and consumption. The place of food in society is dependent on the way in which various technologies are deployed throughout this narrative and how these may or may not help in our responses to the two great challenges confronting humanity today: social justice for all and the stewardship of Planet Earth in the face of climate change. It is important that young people learn about this in school in the light of both sustainable food production and nutrition. This paper will discuss how knowledge and understanding of this narrative, the embedded technologies and these challenges might be taught as the basis for a secondary school food technology course.

Keywords Food Technology, Curriculum, Pedagogy, Social Justice, Stewardship,

1. INTRODUCTION

As young people grow up, they engage with food through the meals they eat at home which depends on the way their families buy, prepare and eat food. This is mainly dependent on the food made available to them in supermarkets and food stores although some people can grow some of their own food. These retail outlets are part of a supply chain that is global in that a variety of food staples are grown in different parts of the world and exported to other countries in which they are processed in various ways to become the food items people buy and eat. This paper adopts the position that this Narrative of Food may be used as the basis for teaching food technology in secondary schools (learners aged 11 – 16 years). This paper is in six parts. Part 1 explores the Narrative of Food in terms of how it might be presented to and then interrogated by learners. Part 2 describes some of the technologies that operate within this Narrative. Part 3 considers the causes of malnutrition. Part 4 identifies the issues to be addressed if food production is not to contribute to global warming. Part 5 describes five ways in which food technology might be used to address the apparently conflicting requirements of feeding the world and reducing global warming. Part 6 presents concluding remarks which consider ways forward for curriculum development.

2. EXPLORING THE NARRATIVE OF FOOD

2.1. Presenting the narrative to learners

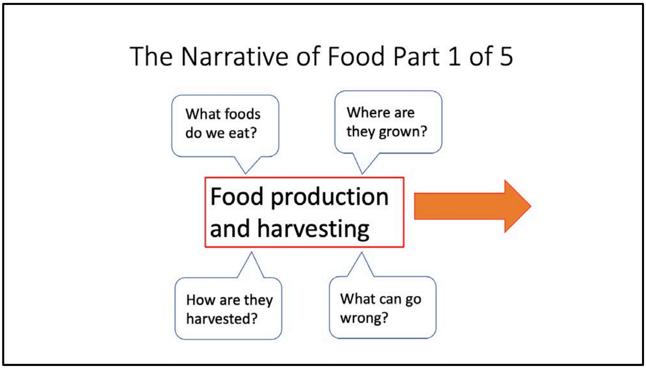
The Narrative of Food is structured in five sections: 1) production and harvesting, 2) storage, 3) preservation and processing, 4) sale and distribution, and 5) preparation and consumption. The technologies deployed in this narrative vary in the extent to which they are food specific in their original intention. Some are directly concerned with the intrinsic nature of food as a material and the way it behaves. Plant breeding to increase crop yields is an example. Others will have a more tangential, but no less significant, relationship within the narrative. The development of tools to aid harvesting is an example. Both types of technology are considered to achieve a holistic view. If learners are to understand the Narrative of Food, then providing them with the 'Big Picture' is important so that they can relate the various stages to their own lives. Such a picture will provide a broad sweep overview with just enough detail to enable learners to grasp the narrative without being overwhelmed by the underlying intricacies. The cognitive load (Willingham 2021) of the details will almost certainly confuse learners.

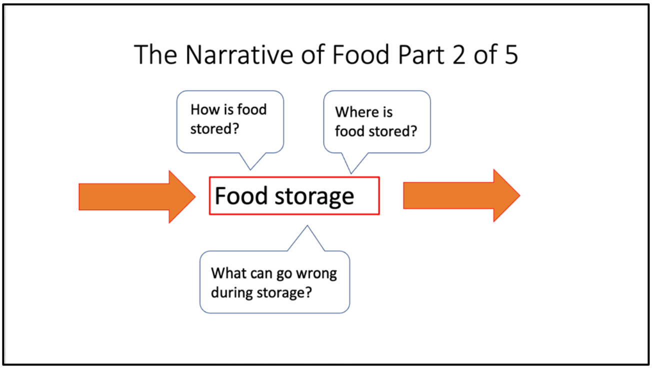
The approach to the Narrative of Food taken in this paper is to see it as a linear sequence involving the five stages listed above. Presenting this sequence all at once, even by means of a mix of diagrams and comments, is likely to overwhelm learners so it will be important to build up the sequence a stage at a time until the entire sequence is complete. In addition to avoiding overloading the learners with information this has the following advantages:

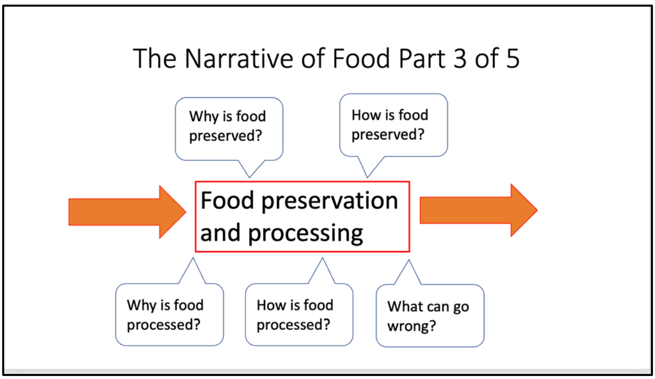
- The teacher can ask the learners about each stage, so he/she has some sense of their existing knowledge and understanding.
- The class can build up a shared appreciation of what they, as a learning community, already know and believe (some of which may well be erroneous as revealed by the ground-breaking work of Rosalind Driver (Driver 1983).
- The teacher can use this to inform the presentation as she/he teaches the class about each stage.
- The teacher can also ask question that provoke the learners to re-evaluate their knowledge and the place of that stage in the sequence in their lives.

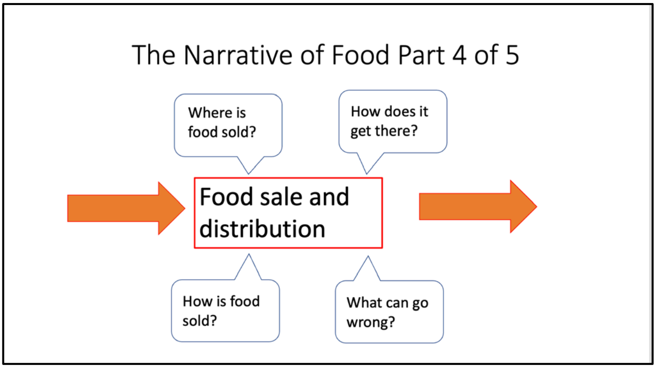
Figure 1, *The Narrative of Food in Five Parts*, shows possible presentation slides, along with possible questions, that might be used to build up a big picture of the narrative of food.

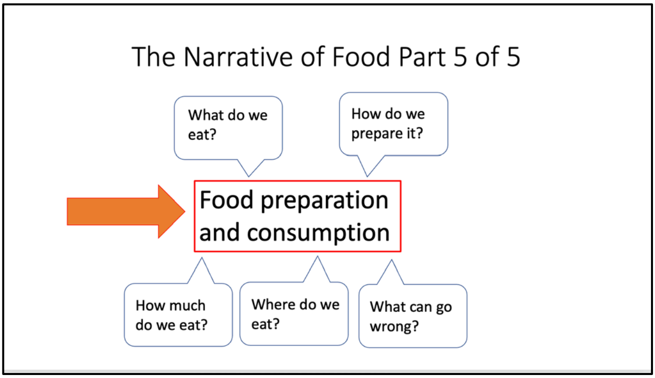
Figure 1
The Narrative of Food in five parts











2.2. Interrogating the narrative

The quality of question-and-answer session accompanying the presentation is crucial to learners' engagement with and understanding of the Narrative of Food. In responding to the learners' comments, it is essential to treat their answers with respect especially those answers that reveal misapprehensions. Many learners, especially those living in cities have little contact with farming and the origins of their food and their ideas will often be incorrect. Only the learners themselves can correct these misconceptions in the light of the information the teacher presents. If they are made to feel foolish it is highly likely they will become resentful and cease paying attention. The questions used by the teacher at each stage all include the question "What can go wrong?" This is an important enquiry as it can be used to highlight issues around food security and nutrition.

3. THE TECHNOLOGIES IN THE NARRATIVE

The technological solutions used at the various stages in the narrative will be dependent on the context. Consider the growing of food. The tools used by subsistence farmers (some 25% of the world population (Rapsomanikis, 2015)) are not dissimilar to those used by such farmers many thousands of years ago, the sickle, scythe, and hoe. The technological response of most recent farming has been ever more mechanisation to increase both capacity and efficiency. Hence the tools available to modern farming now incorporate satellite navigation and robotics into both planting and harvesting. Drones with sensors capture real time data about soil conditions on farms. Satellites are used to accurately predict weather conditions and pest migrations. Autonomous vehicles can now plant and harvest on very large scales with only minimal human oversight. What a paradox – in many parts of the world we have millions of subsistence farmers using indigenous knowledge with tools and methods developed in the distant past to literally scrape a living for themselves and their families whilst at the same time we have modern farming practices elsewhere producing and harvesting vast amounts of crops, informed by sophisticated technology, and implemented through automation requiring minimal human involvement in the activity. The use of driverless tractors to help harvest wheat is already available (Reichenberger 2018). Utilising modern technology can take place in some countries that usually rely on traditional methods. In Kancheepuram district in the southern state of Tamil Nadu, in India, drones are being used to spray crops with fertiliser and pesticides to overcome the shortage of agricultural workers caused by migration to the cities (Mukharj, 2023). Learners will need to appreciate the role of technologies in the different stages of the narrative and consider both the benefits and costs of such applications.

4. DEALING WITH MALNUTRITION

4.1. Over-nutrition in developed countries

Being overweight or obese is a major form of malnutrition in developed countries. The government in England, is seriously concerned about the nation's health with particular regard to the impact of poor dietary choices on the cost of the National Health Service (NHS). Foresight is a department within the UK Government Office for Science which is tasked with enabling civil servants to think about the future in terms of the likely impact of new and emerging technologies and societal trends. (See https://www.gov.uk/government/groups/futures-and-foresight#who-we-are) As early as 2007, Foresight reported that the predicted increase in obesity was a ticking time bomb as far as health service costs were concerned (Department for Innovation, Universities and Skills, (DIUS) 2007a) This extract from the summary of key messages (DIUS, 2007b) indicate the seriousness of the situation:

> By 2050, Foresight modelling indicates that 60% of adult men, 50% of adult women and about 25% of all children under 16 could be obese. Obesity increases the risk of a range of chronic diseases; particularly type 2 diabetes, stroke, and coronary heart disease and also cancer and arthritis. The NHS costs attributable to overweight and obesity are projected to double to £10 billion per year by 2050. The wider costs to society and business are estimated to reach £49.9 billion per year (at today's prices).

Written just over 15 years ago this provided a stark warning. Prescriptions for Type 2 Diabetes caused to a large extent by lifestyle choices leading to being overweight and obese are costing the

NHS in England more than £1 billion a year (Ives, 2018). The latest data from the Health Survey for England (2019) paints a similarly bleak picture with these headlines:

- Among adults 16 and over, 68 % of men and 60% 0f women were overweight or obese.
- Among children, 18% of boys and 13 % of girls were obese.
- Children with obese parents were more likely to be obese.
- Adults living in the most deprived areas were the most likely to be obese.

According to Henry Dimbleby (2023), citing the World Health Organisation, one of the contributory causes of poor dietary choice is the ready availability of inexpensive, prepared food that is high in fat, sugar, and salt. At a time when many families are struggling financially, ready meals from the supermarket or from a fast-food outlet provide an affordable, if unhealthy, source of food. Research has indicated that the numbers of fast-food outlets can double the chances of becoming obese (Briggs, 2014) and UK high streets currently have the highest concentration of fast-food outlets since 2010 (Homer, 2018).This is an example of how those who are poor in developed countries find themselves in a situation in which they appear to have little choice but to adopt an unhealthy diet in which there is an overabundance of calories combined with ingredients that are intrinsically unhealthy. The impact of the pandemic made matters worse; according to Keeble, Adams and Burgoine (2023), the number of outlets accessible online in the most deprived areas increased during the pandemic. It is clearly unjust that the poor in the UK and other such countries find themselves in this situation. If one looks at such diets through the lens of stewardship of Planet Earth many of the ingredients used to produce and deliver such food carry a heavy carbon footprint and also deplete the Planet's ability to absorb carbon dioxide. As Foresight acknowledged confronting this issue is a major challenge requiring a coordinated partnership between government, science, business and civil society and it is interwoven with efforts to combat climate change.

4.2. Under-nutrition in developing countries

Under nutrition makes children in particular much more vulnerable to disease and death. According to the WHO (World Health Organisation, 2021) around 45% of deaths among children under 5 years of age are linked to under nutrition. These mostly occur in low- and middle-income countries. Women, infants, children, and adolescents are at particular risk of malnutrition. Optimizing nutrition early in life—including the 1000 days from conception to a child's second birthday—ensures the best possible start in life, with long-term benefits.

Poverty, in both developed and developing nations, amplifies the risk of, and risks from, malnutrition. People who are poor are more likely to be affected by different forms of malnutrition. In addition to lessening opportunities and aspirations, malnutrition increases health care costs, reduces productivity, and slows economic growth, which can perpetuate a cycle of poverty and ill-health. The impact of global warming is intertwined with the impact of poverty and exacerbates the already deleterious effects of malnutrition hence it is to a consideration of sustainable food production we now turn.

4.3. Sustainable food production

The way we produce and consume food and climate change are intertwined. The World Resources Institute's Report (2019) *Creating a Sustainable Food Future* identifies three important 'gaps' that need to be bridged by 2050:

(i) The Food Gap

- The difference between the amount of food produced in 2010 and the amount necessary to meet likely demand in 2050; 56% more crop calories will be needed compared to that produced in 2010.

(ii) The Land Gap

- The difference between global agricultural land area in 2010 and the area that will be required in 2050—even if crop and pasture yields continue to grow at rates achieved in the past. 593 million hectares of extra land will be needed, an area nearly twice the size of India.

(iii) The Greenhouse Gas (GHG) mitigation Gap

- The difference between the level of annual GHG emissions from agriculture and land-use change in 2050, which we estimate to be 15 gigatons (Gt), and a target of 4 Gt that represents agriculture's proportional contribution to holding global warming below 2°C above pre-industrial temperatures. Holding warming below a 1.5°C increase would require meeting this 4 Gt target *plus* freeing up hundreds of millions of hectares for reforestation.

The report identified spurring technological innovation as one possible response to the 'gaps'. Some possible innovations are described in the next section.

5. CONFRONTING CONFLICTING REQUIREMENTS THROUGH FOOD TECHNOLOGY

The contribution of farming to global warming juxtaposed to the need for increased food production in the light of population increase creates a situation in which there are conflicting requirements. The following five approaches provide ways in which these conflicts might be addressed through food technology. Learners should be introduced to these and similar approaches in a modern food technology course.

5.1. Increasing food production without expanding agricultural land

Viviano & Locatelli (2017) report that the Netherlands is a country with very little land available for agriculture yet is the second largest global exporter of food by dollar value after the US. It has invested heavily in 'smart' greenhouses which allow farmers to closely control growing conditions and use fewer resources like water and fertilizer. The farming of tomatoes provides a compelling example. The area devoted to growing this crop is only 6.9 square miles but has a yield of 144,352 tons per square mile (greater than anywhere else in the world) with a water footprint 25 times less than the global average. This is achieved through large scale greenhouse cultivation growing plants without soil in nutrient rich solutions.

5.2. Developing crops that are resistant to climate extremes

Gene editing is different from genetic modification in that it does not require the introduction of genes from a different organism. Through such gene editing it is possible to rapidly create plants that are drought resistant, immune to disease and improved in flavour (Niler 2018). And importantly, they need not be labelled as genetically modified (GM) crops and may thus escape the notice of supermarket customers, hence avoiding the backlash suffered by earlier GM crops. This is providing the various food regulation authorities do not classify them as GM crops and insist that they are labelled as such, which would then severely limit their commercial viability and use in combating world hunger.

5.3. Growing food in ways that do not contribute to climate change

Precision fermentation is the use of genetically engineered micro-organisms to produce animal products and this process is being used to produce milk; hence, in addition to milk itself it is possible to develop a range of dairy free milk-based products – ice cream, yoghurt, cheese. Initially these are likely to appeal to those who wish to adopt a diet that does not include food derived from animals but as the prices become more competitive such products will move into the mainstream (Lawton 2021). It is widely acknowledged that production of meat, particularly beef, is bad for the planet and a very inefficient process (Natural History Museum 2022). Hence the idea that we might be able to simply grow meat in bioreactors, using our knowledge of biotechnology is very appealing. Staring with a small sample of cells from an animal the cells are grown in a bioreactor such that they cling to an edible scaffold to create 3D tissue i.e., meat. This meat is then harvested and turned into food products without the need to clear forests for grazing, raise herds of cattle on the cleared land, slaughtering and butchering their carcasses etc. with the attendant environmental damage. This might be described as 'cellular agriculture' (Lawton, 2020).

5.4. Utilising foods from unusual sources

McMillan (2018) claims that whilst eating insects is perfectly acceptable in some cultures, (e.g., Thailand and Mexico), this faces considerable consumer resistance in other countries. However, they are finding a market in the United States as high protein animal feed or ingredients for processed foods. McMillan (ibid) also claims that crickets appeal as a food material because they offer more protein and micronutrients per pound than beef, thrive in dark densely crowded conditions, thus allowing for factory-scale production on a tiny footprint. And unlike some large hog and cattle farms with their manure lagoons, they produce relatively little waste. Seaweed is also an acceptable food in some parts of the world; particularly Asia but is less so in other jurisdictions. However, this may change as there is a burgeoning kelp industry off the coast in Scotland (Shaw 2021). Kelp is high in vitamins and minerals and there are now many ways to introduce it into our food (Sea Food Nutrition Partnership 2021).

5.5. Providing alternatives to ruminant meat consumption

Niall Firth (2018) cites the advantages of plant-based meat alternatives to meat consumption for the planet: lower caron footprint, lower water consumption, and lower land use compared with beef production and such products are now becoming mainstream. For example, Macdonald's now has on its standard menu in the UK a vegan burger made with a plant-based patty co-developed with Beyond Meat® featuring vegan sandwich sauce, ketchup, mustard, onion, pickles, lettuce, tomato, and a vegan alternative to cheese in a sesame seed bun. (McPlant™ 2022).

6. CONCLUDING REMARKS

This paper has described five features that should be considered in developing a food technology curriculum for the secondary school (learners aged 11 – 16 years) based on the Narrative of Food: how the narrative might be presented to and interrogated by learners, some of technologies currently operating within the narrative, malnutrition, sustainable food production and technologies pertinent to this endeavour. There is an elephant in the room: teaching young people to cook. This is a laudable endeavour but not necessarily one that should take place in a food technology curriculum. This issue and others are considered in greater depth in Beaumont (2023) a chapter in Food Futures in Education and Society (Singh, G., Turner, A. & Rutland, M. (eds) 2023). As far as the UK is concerned the recent publication of the National Food Strategy (Dimbleby, 2022) suggests that Ofsted (Office for Standards in Education, Children's Services and Skills, a non-ministerial department of the UK government), should set up a team to create and publish a food and nutrition "research review", as it has started doing with other subjects. If such a research review is set up, it is to be hoped (a) that its terms of reference are wide enough to consider developing a curriculum that teaches across the narrative of food as outlined in this paper and (b) the contributors include stakeholders from academia, education, industry, and government.

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All you wanted to know about D&T but were afraid to ask?

HildaRuth Beaumont, Institute of Education UCL, hildaruthbeaumontt@btinternet.com
Torben Steeg, Manchester Metropolitan University, torben@steeg.co.uk

ABSTRACT

Torben Steeg and Hilda Beaumont have written a short book for design & technology teachers both in England and abroad; to support heads of department in particular although we expect the book to be useful to teachers in training. The publisher is Routledge, and the title is *Design and Technology in your School: Principles for Curriculum, Pedagogy and Assessment*. In writing this book we have called on the expertise of those who have significantly influenced the developing nature of the subject by inviting them to be critical friends of our writing and in some cases by contributing short pieces themselves. As a result, the content was not restricted to the thoughts of Torben and Hilda but was able to include voices from across the community of practice. This paper will describe our reasons for writing the book, the structure of the book, the devices used to support active engagement with the text, the contribution of critical friends and Thought Pieces, and the dealing with contentious issues. In the Concluding Remarks the paper discusses the place of the book in subject's current state of uncertainty.

Keywords: Curriculum, Pedagogy, Assessment, Design & Technology

1. INTRODUCTION

This paper describes the authors' approach to writing the book *Design and Technology in your School: Principles for Curriculum, Pedagogy and Assessment.* It is a short book for design & technology teachers in secondary schools (for learners aged 11 – 16 years) both in England and abroad. It is designed to support heads of department in particular although we expect the book to be useful to teachers in training. The publisher is Routledge. The paper is in seven parts. Part 1 outline our reasons for writing the book. Part 2 describes the structure of the book; Part 3 describes devices to support active engagement with the text and Part 4 the contribution of critical friends who commented on our writing as we developed the book. Part 5 describes the Thought Pieces written by experts in particular aspects of design & technology education. Part 6 discusses the way the book deals with contentious issues. The final part presents concluding remarks concerned with the uncertain future of the subject and how the book might be used.

2. OUR REASONS FOR WRITING THE BOOK

The situation with regard to design & technology is undoubtedly uncertain. Some see the subject as broken citing the continuing decline in uptake at GCSE level for over 20 years and recent changes to both the National Curriculum and GCSE Specifications. These changes, they argue, have led to a subject that is too demanding for those young people who used to enjoy studying it. The Design & Technology Association believe that it can be mended. Others are arguing that nothing less than the introduction of an alternative subject can save this important area of the curriculum. We think that it is important to have a clear statement of how a curriculum for design & technology, as originally conceived for the National Curriculum in England, can be successfully constructed, taught and assessed and to identify the support required for this to happen. Hence, we have written this book.

3. BASIC STRUCTURE

The overall structure if the book is shown in Table 1.1 which lists the chapters and the main sections within each chapter. To some extent these are what one might expect, the usual suspects: justifying, understanding, planning, teaching, and assessing but we also added two more chapters. One discusses issues that are of particular relevance at the time of writing. Recently there has been debate about the white washing of curricula (Akala 2019) and the way in which the curriculum is gendered (Unstereotype Alliance). Clearly the impact of global warming and pollution are matters of current concern. And the authors have long held the view that the way certain technologies play out in society by being disruptive is insufficiently acknowledged in the design & technology curriculum. The other describes ways in which design & technology may be supported which the authors feel is particularly important at this time when the subject is under threat.

Table 1. Book structure

Chapter 1 Justifying design & technology	**Chapter 5 Teaching design & technology**
Design & technology's role in the curriculum Four possible justifications Revisiting the role of design & technology in the curriculum	How learning happens Teaching technical understanding Teaching Making Teaching designing Teaching critique Digital Designing and Making
Chapter 2 Understanding design & technology	**Chapter 6 Assessing design & technology**
Philosophy of technology Philosophy of design The place of values in design & technology Substantive and Disciplinary Knowledge in Design & Technology The place of skills, knowledge, understanding and values in intervening Relationships with other subjects	Purposes of assessment The messy nature of progress Integration of assessment into curriculum planning and implementation Feedback as part of "In the moment" assessment Feedback as part of "End of task" assessment Identifying impact Public examinations

Chapter 3 **Important Issues**	**Chapter 7** **Supporting design & technology**
Decolonising D&T Gender Disruption Global Warming Pollution and waste	Liaison with primary schools Enrichment & Enhancement Activities STEM and STEAM Research Continuing Professional Development Maker Education Interested parties Vision and Mission statements for design & technology
Chapter 4 **Planning your design & technology curriculum**	
Content Resources Activities Organisation and strategy Ofsted	

We must make it plain from the outset that we have not considered the place of food as part of design & technology within this book. There are several reasons for this. The place of food within National Curriculum design & technology has been marginalised by the insertion of a section at each key stage devoted to cooking and nutrition (Department for Education 2013). Food as a material to be used in design & technology was removed from all GCSE design & technology specifications in 2016 and GCSE Food Preparation and Nutrition was introduced at the same time (Department for Education 2015). Hilda has written separately about the teaching and learning of food technology in *Food futures in education and society* (Singh, Turner, & Rutland, 2023).

4. DEVICES TO SUPPORT ACTIVE ENGAGEMENT WITH THE TEXT

All chapters include Pauses for Thought. These are designed to stimulate the reader to think about what has just been read before moving on. Some of the Pauses for Thought ask questions of the reader to encourage individual reflection but many suggest questions that might be discussed with colleagues as a means of building collaboration and collegiality which both of us believe are important for developing a voice for design & technology that is articulate and taken into account by colleagues from other subjects and senior leaders. In addition to Pauses for Thought Chapter 2 also contains a series of Curriculum Considerations each related to a specific part of that chapter. This are summarised in Table 1.2. These are to encourage teachers to develop aspects of the curriculum that they may have, in the past, neglected. Our view is that any curriculum should be seen as dynamic in that it will have embedded within it conflicting requirements that can only be addressed by those teaching it on an on-going basis.

Table 2. Curriculum Considerations

Area of considerations	Features to consider
Concerning Carl Mitcham's thinking about the philosophy of technology	Engaging young people with a) the sort of artefacts they should design and make, b) the knowledge they will need to discover, c) the sort of activities they should pursue and d) the extent to which volition should be tempered
Concerning the philosophy of design	The feasibility of meeting a wide range of criteria for any item learners design and make. The idea of community design as exemplified in approaches to design taken in developing countries in contrast to the prevailing western view of designer as 'individual hero'. The importance of challenging the idea of a linear economy with circular economy ideas
Concerning values	Developing a vocabulary for values thinking Enabling progression in values thinking Engaging in the politics of values thinking
Concerning substantive and disciplinary knowledge	Managing the balance between talking about important issues and responding through practical activity in the classroom The difficulties associated with assessing learners' value positions Managing open starting points for design activity
Concerning relationships with other subjects	That design & technology and other subjects might benefit from thinking about the ways each other assess learners' progress The importance of maintaining subject integrity Identifying links that are of mutual benefit

THE CONTRIBUTION OF CRITICAL FRIENDS

We relied on several members of the design & technology community of practice to comment on our writing as we developed the book. They responded with generosity and insight and the result is significantly better because of their comments. Hence, we are grateful to the critical friends listed in Table 1.3 along with the sections they commented on, but we must add that we take responsibility for the text that appears in the book.

Table 3. Critical friends

Critical friend	Commented on
Nick Givens Senior Lecturer, College of Social Sciences and International Studies University of Exeter (retired) Associate at University of Exeter	Decolonising design & technology Global Warming
Jonas Hallström Professor of Technology Education, Technology and Science Education Research Linkoping University	Philosophy of technology
Mary Myatt Education adviser, writer and speaker	Substantive and disciplinary knowledge
Mike Martin School of Education, Liverpool John Moores University	Values in design & technology
Kay Stables Professor of Design Education Goldsmiths, University of London	Philosophy of design

5. THE THOUGHT PIECE CONTRIBUTIONS

We have deliberately written a short book and are conscious that this is a mixed blessing. On the one hand the shortness required us to write in a disciplined and focussed way, making key ideas easier to access but on the other hand there is the possibility that we had not given sufficient consideration to some of the key ideas. To mitigate this, we asked other authors, who are experts in particular aspects of design & technology education, to write 'Thought Pieces' in which they make further comment on a key idea. In this way we hoped that the expertise of the wider design & technology education community would inform the book. We were not disappointed. The following gave unstintingly of their time, experience and thoughtfulness in contributing Thought Pieces that make significant additions.

(i) Louise Attwood Head of Curriculum – Design & Technology for the Awarding Organisation AQA
(ii) Ed Charlwood Expert teacher of engineering and design & technology and educational consultant regarding curriculum and pedagogy
(iii) Dr Alison Hardy Associate Professor, writer, researcher, and podcaster at Nottingham Trent University
(iv) Philip Holton Senior Strategy Manager for Pearson UK Schools
(v) Dr Dawne Irving Bell Professor of Learning and Teaching at BPP University.
(vi) Richard Kimbell Emeritus Professor, Goldsmiths University of London.
(vii) Dr Matt McLain School of Education, Liverpool John Moores University
(viii) Dr Paul Mburu Head of Design & Technology Department, Harlington School
(ix) Andy Mitchell Ex Deputy CEO The Design and Technology Association
(x) Dominic Nolan Corporate Social Responsibility Leader, Kyndryl UK & Ireland
(xi) James Pitt Honorary Professor of Education at the Amur State University of Humanities and Pedagogy, Russia
(xii) Ulrika Sultan Educator, and researcher at Örebro University
(xiii) Dr Malcolm Welch Professor Emeritus at Queen's University, Kingston, Ontario

The main thrusts of the Thought Pieces are summarised in Table 1.4. These are clearly relevant to the content of the particular chapters and while one could argue that we could have included this in our own writing we feel that engaging others to do this gives rise to additional and different thoughts which have an added status and prominence. Also, we were able to write a short response to each of the Thought Pieces starting with the phrase, "What are we to make of …" which further increase the contributions made by the Thought Piece authors.

Table 4. Thought Pieces

Author of Thought Piece	Topic of the Thought Piece	Main thrust of the Thought Piece
Alison Hardy In Chapter 1	Justifying design & technology	Alison argued that in justifying design & technology we need to match arguments to the positions of the stakeholders we are trying to convince of its worth and widen the discussion to include learners.

Andy Mitchell In Chapter 2	Starting points in design & technology	Andy argued that in using open tasks to enable creativity and learner ownership it was important to teach relevant substantive and disciplinary knowledge. He noted that whilst in some cases it was important for learners to design AND make outcomes in response to the task, he could justify learners developing design proposals which they did not make. In developing proposals that learners did not make it was possible for them to engage with global problems.
Ulrika Sultan In Chapter 3	Gender for design & technology teachers	Ulrika challenged the prevailing binary position that most adopt in western society categorising learners as boys or girls as opposed to treating them as individuals with their own preferences with regard to interests, attitudes and aspirations. She acknowledges the pressure on learners to conform to gender stereotypes but argued that we should help them resist this and a first step here is for teachers to challenge such stereotypes themselves.
Dominic Nolan In Chapter 3	Global Warming for Design & Technology teachers	Dominic makes a strong case for organisations developing their own carbon literacy education programmes in that they not only inform about global warming issues but, crucially, empower people to respond in ways that make a difference and challenge the selfishness, greed, and apathy that bedevils attempts towards net zero.
Philip Holton In Chapter 4	Physical Resources as a legacy approach	Phil argues for learners to produce proof of concept models in response to a design brief as opposed to a high-quality final prototype suggesting that this is the way professional designers work. To accommodate this, he outlines an approach to learning in KS3 that utilises simple tools and materials but enable learners to make connections between the tools and materials that might be used to produce a more physically robust outcome. This removes the subject from the dead hand of past requirements of craft practice.
Paul Mburu In Chapter 4	Developing teams as a key leadership strategy	Paul makes a strong case for a team approach to the way a design & technology department develop and implement their curriculum. He underpins this with the importance of creating an environment where the sharing of good practice is seen as developmental rather than judgemental and members of staff draw upon experiences gained through working in a variety of teaching and planning teams. In his view this will lead to significant individual professional development and improvement of the department in the long term.
Matt McLain In Chapter 5	Demonstration; a pedagogy for teaching	Matt makes the case for learners acquiring a limited set of useful making skills through demonstration and practice as a gateway to developing designing skills. With this approach they design what they can make as opposed to developing high levels of practical craft skill in a narrow disciplinary area as an end goal.
James Pitt In Chapter 5	Some wider considerations	James argues that through critique, design & technology can play its part in contributing to liberating education and help young people develop a vision of a future worth wanting and the abilities to

		achieve this. Critiquing products, systems and technologies he suggests are central to design & technology learning. This suggestion can be used as a vehicle for encouraging radical thinking. It can be an antidote to mindless populism, uncritical consumption, and echo-chamber prejudice.
Ed Charlwood In Chapter 5	Moving forward with digital design & technology	Ed argues for the use of digital tools as the means to increase learners' agency. Not only in their ability to be creative in conceiving innovative designs through CAD but also in realising those designs through CAM. He realises that this will involve many teachers rethinking long held and cherished beliefs about the importance of craft practice but is firm in his opinion that digital designing and making should become a core feature of design & technology alongside the use of physical materials and components in exploring design ideas.
Malcolm Welch In Chapter 6	Classroom conversations	Malcolm explores the role of talking in the design & technology workshop as a means of helping learners develop the conceptual understanding to make sound design decisions. A key feature of such conversations was the way that teachers use questions in response to learner's questions to help learners progress their thinking as opposed to telling learners the answers. This approach requires learners to think more deeply and hence achieve the cognitive shifts required for understanding.
Richard Kimbell In Chapter 6	All assessment judgements are comparative	Richard makes the case for assessment to be carried out by means of comparative judgements by which it is possible to develop a rank order of learner performance. This he claims is more valid and more reliable than attempting to match learner's performance to criteria statements linked to numerical scores which are then used to give learners a 'mark' from which a grade is then awarded. Richard laments the fact that the examination system adopts the performance criteria approach when a properly workable system of direct comparative judgment had been developed a decade ago at Goldsmiths University.
Louise Attwood In Chapter 6	Valid assessment: grades and marks	Louise describes in some detail the approaches that AQA use to assess learner's GCSE performance which she argues includes to some extent the comparative pairs approach advocated by Richard Kimbell. She also describes how awarding organisations are required to use statistical information to ensure comparability of standards between years and prevent grade inflation and she acknowledges the importance of teacher professional judgement throughout the process.
Dawne Irving Bell In Chapter 7	Support for Curriculum Collaboration	In discussing how teachers might respond to STEM and STEAM initiatives Dawne advocates the forging of strong relationships across the curriculum both within teachers' own schools and between different schools citing design fiction (very similar to designing without making) as a learning activity suitable for

		collaboration. She views this as an important strategy to enable learners to challenge technological determinism in the identification and pursuit of a future worth wanting.

6. DEALING WITH CONTENTIOUS ISSUES

We identified five areas which we considered to be contentious issues:

6.1. Decolonising design & technology

A key question for us in considering decolonising our subject was, 'How might a design & technology curriculum enhance or diminish the engagement and success of learners from minoritized backgrounds?" To enhance engagement, we believed it was essential that all learners 'felt at home' within the design & technology curriculum echoing the point made by Maya Angelou in All God's children need travelling shoes (1987) that home was a safe place where we can go as we are and not be questioned. This led us to affirm the importance of the visibility in the curriculum of those from minoritized backgrounds who had been, and are being, successful in design & technology related fields of endeavour and as part of this to challenge the Europe - centred colonial lens which paints a whitewashed retelling of the history of empire that speaks only to its "successes," whilst omitting its evils, the voices of the oppressed and the lasting legacy of imperialism today.

6.2 Gender in design & technology

In Chapter 1 we identified four justifications for teaching all young people design & technology: personal empowerment, preparation for citizenship, cultural transmission, and preparation for work, particularly in STEM occupations. Our position is that each of these justifications are equally appropriate for both boys and girls, but we find that this isn't always reflected in girls' career choices or society's expectations of how young women or young men should operate in the world. Challenging gender stereotypes is important, and we considered that it might be useful to introduce activities in ways that were gender sensitive such that both boys and girls are enabled to cross the gender stereotype divide.

6.3 Disruption

In developing technological perspective in young people, we thought it important that they were introduced to the ideas of certain technologies being disruptive in that they upset the status quo, alter the way people live and work, reorganise financial and social structures and lead to entirely new products and services (Manyika J et al, 2013). The authors, working with Nick Givens, have identified, and discussed 9 disruptive technologies they consider highly suitable for inclusion in the secondary school curriculum (Barlex, Givens and Steeg 2020) and have suggested in which areas of the curriculum they might best be taught. We identified three categories of disruption:

deliberate, incidental, and cultural. In the book the realities of disruption to everyday life were considered through the possible impact of the identified disruptive technologies on transport.

6.4 Global Warming

Although climate change denial is on the wane, we thought it important to present the evidence (MacKay 2009) and information about the Intergovernmental Panel on Climate Change (IPCC) and details of their findings along with the predicted effects of global warming on climate and efforts of governments to adapt to and mitigate these effects including the outcomes of COP27. Concern over tipping points was discussed along with the importance of climate justice. The role of technologies in 'rescuing' the planet was considered including carbon capture, nuclear power, a hydrogen economy, and renewable energy sources. Possible personal responses to the issue were considered and how the these can inform national and international responses to the situation in the light of Gus Spence (Holtam 2022), Dean of the Yale School of Forestry and Environmental Studies comment:

> I used to think the top environmental problems were biodiversity loss, eco system collapse and climate change. I thought that with 30 years of good science we could address these problems. But I was wrong. The top environmental problems are selfishness, greed, and apathy – and to deal with those we need a spiritual and cultural transformation – and we scientists don't know how to do that.

6.5 Pollution and waste

Here the focus was on developing a circular economy identifying its three key principles: eliminating waste and pollution, circulating products and materials at their highest value, and regenerating nature. The biological and technical cycle comprising a circular economy were discussed in some depth and exemplified using case studies. The following three important ideas that learners need to be taught if they are to understand the idea of a circular economy were identified: systems thinking (which can be used in designing for circularity to minimise waste), life cycle analysis and designing for sharing or leasing as opposed to selling which challenges the idea of personal ownership.

7 CONCLUDING REMARKS

We have noted that the situation with regard to design & technology is uncertain. The Design & Technology Association believe that the subject can be reinstated through modification and in the final chapter *Supporting design & technology* there are links to the recommendations made in the Design & Technology Associations *Reimagining D&T Report* (Design & Technology Associations 2023). Others, for example Philip Holton at Pearsons, argue that nothing less than the introduction of an alternative subject can save this important area of the curriculum. Hence, he is spearheading efforts in collaboration with the Department for Education to introduce a new subject to be called *Responsible design & innovation* at both KS3 and KS4. This is not without its critics, but it is providing a useful forum for discussing future developments. The teaching of the subject, in whatever guise, needs to be responsive to current events in the world outside school. To emphasise this, we have included two Stop Press items of particular relevance at the time of going to press: one concerning recent developments in AI focusing on the use of the Chatbot ChatGPT in developing responses to design briefs and one concerning recent comments from the Climate Change Committee criticising the way the UK government is putting in place the means to adapt to the impact of climate change. However, the development of the subject plays out we believe that our book *Design and Technology in your School: Principles for Curriculum, Pedagogy and Assessment* will be of use to teachers and heads of department in the coming years. With this in mind we will be developing additional and associated web-based resources on our web site (https://dandtfordandt.wordpress.com) and are planning to work with those departments who wish to use the book and its associated resources for curriculum and professional development.

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Implementation and Analysis of a Spatial Skills Course for Secondary Level STEM Education

Urša Benedičič, Technological University Dublin, ursa.benedicic@gmail.com
Liam Maquet, Technological University of the Shannon
Gavin Duffy, Technological University Dublin
Rónán Dunbar, Technological University of the Shannon
Jeffrey Buckley, Technological University of the Shannon
Sheryl Sorby, University of Cincinnati

ABSTRACT

High spatial skills have been directly linked to enhanced performance in STEM disciplines, with improvements in spatial skills linked to an increase in female retention at the university level. Spatial skills development and direct training are well researched and implemented within university level engineering education but are less defined at earlier stages of education. It is hypothesised that a spatial intervention implemented at the secondary level could be beneficial in order to boost student performance in STEM, where it still influences their interest in subjects and future career paths. The purpose of this paper is to present the implementation process of a spatial intervention in Irish secondary schools and the initial analysis of combined teacher and student data. The intervention was implemented with Transition Year (aged ~15 to 16 years old) students. Fifty teachers undertook a tailored professional development training to prepare them to deliver the spatial skills intervention, some of which then took part in various qualitative data gathering activities. The intervention was delivered to approximately 1500 students. They were administered a range of psychometric tests, including multiple spatial tests and a fluid reasoning test to investigate their development in a variety of cognitive aspects. This paper will focus on investigating the possible relationships between teacher spatial ability and student gains in spatial ability. The findings of the study were positive, indicating the successful implementation of the intervention and showing promise for future iterations.

Keywords: Spatial skills, professional development, pedagogy, secondary education, student outcomes, student participation

1. INTRODUCTION

Traditionally, it was believed that STEM (Science, Technology, Engineering, Mathematics) success was primarily supported by the development of mathematical and verbal skills (Marrero et al., 2014). However, a longitudinal study conducted by (Wai et al., 2009) showed that spatial skills are strongly predictive of STEM participation and attainment – even more so than the development of mathematical and verbal skills. Additionally, it displayed the importance of developing spatial skills by the age of 13, as this may impact students' career choices. Research from the Technology and Engineering field has established the importance of spatial skill development in student thinking when problem-solving (Duffy, 2017), increasing their working memory capacity when working with graphical problem-solving tasks (Buckley et al., 2019; Delahunty et al., 2020), supporting female participation in Engineering, and increasing students' performance in subsequent engineering courses (Sorby & Veurink, 2010).

An Irish national study (Bowe et al., 2016) highlighted the underdevelopment of spatial skills in secondary schools. Therefore, the purpose of this study is to develop spatial skills at secondary level by implementing an established course, named Developing Spatial Thinking (DST), initially designed for undergraduate engineering students (Sorby & Baartmans, 2000). This course has been chosen due to its previously determined effectiveness in developing secondary school students spatial skills and motivating more female students to enrol in science and mathematics subjects (Sorby, 2009). Since teacher Professional Development Programs (PDPs) are essential in developing in-service teacher's expertise (Garet et al., 2001), a spatial intervention has been implemented in collaboration between the Professional Development Service for Teachers (PDST), two Irish Higher Education Institutions co-authoring this paper, and the University of Cincinnati (UC). This approach was adopted to not only investigate the effectiveness of the course in an Irish secondary level context, but to provide the necessary support for the teachers involved.

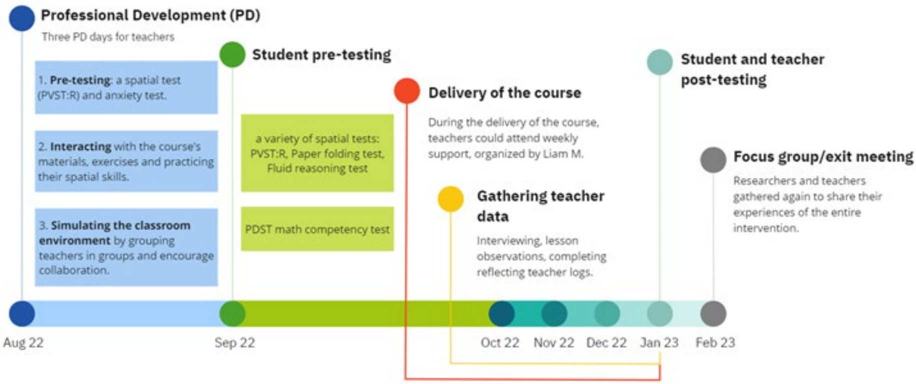
In this study we aimed to answer the following research questions with the objective to better understand teachers' impact on the effectiveness of the course:

- RQ 1: What is the relationship, if any, between teachers' spatial ability and the extent to which their students develop their spatial skills?
- RQ 2: What is the effect, if any, of the spatial intervention on teacher spatial skill level?
- RQ 3: What is the effect, if any, of the spatial intervention on student spatial skill level?

2. INTERVENTION DESIGN

The spatial intervention was based on the original DST course, with reduced content, along with professional development provided for teachers involved. The intervention consisted of the professional development and testing activities shown in Figure 1., supportive of the core elements of effective PDPs, which had been trialled during the pilot study from the academic year 2021/2022 (Maquet et al., 2023).

Figure 1.
Description of intervention activities and timeline



This research was conducted in collaboration between Technological University of the Shannon: Midlands Midwest (TUS), Technological University Dublin (TUD), UC, and the PDST. The PDST managed the school recruitment for the project and the organization of professional development (PD) days. These PD days were delivered by both the PDST and experts in the field of technology education from TUS, who added their knowledge and connected the spatial course to graphics education. Educational goals and practical implications of the spatial course were explicitly pointed out to teachers during the PD days and reinforced through suggested lesson plans for individual modules. There was also an attempt to build a stronger teacher community of practice through the spatial course's website, but that has been proven to be difficult to establish (Maquet et al., 2023).

3. DESCRIPTION OF THE SPATIAL COURSE

Based on the key concepts of Piaget's theory of cognitive development (Piaget, 1952), embodied cognition (Leung et al., 2011), self-directed learning (Du Toit-Brits & Van Zyl, 2017), and the benefits of online learning support (Panigrahi et al., 2018), the implemented spatial course comprised of:

- A workbook with spatial exercises where students develop their thinking with the help of hands-on manipulatives (snap cubes and Knex) and sketching activities.
- Online software with simulations and interactive exercises.
- Online mini lectures with video demonstrations and additional resources for self-directed learning and differentiation.
- A teacher guidebook, including answers, sample lesson plans, and module objectives.
- Sample presentation slides for the teacher to use.

The original course consists of ten modules, while only the following six were used for this study: *Surfaces and Solids of Revolution, Combining Solids, Isometric Sketching and Coded Plans, Flat Patterns, Rotation of Objects about a Single Axis, and Reflection and Symmetry.*

4. PARTICIPANTS AND METHODS

The intervention was implemented with Transition Year (TY) (aged from 14 to 16 years old) students and their mathematics teachers. This year is unique to the Irish education system and is meant to promote students' independence and general skill acquisition needed for their desired future careers (Professional Development Service for Teachers, 2023). This school year was chosen due to its fluid curriculum which supported the adoption of the intervention, previously discussed by Maquet (2023). A quasi-experimental study design was implemented to evaluate the impact on spatial skills of the spatial thinking intervention. This paper includes data from a group of 1199 TY students across Ireland. The participating students completed the provided spatial thinking coursework in place of their usual math instruction. This cohort included 488 male and 711 female participants. Participants who self-identified as genders other than male or female were excluded from this paper due to the low numbers (n = 57) which would not result in a meaningful statistical analysis. Recruitment letters were distributed to schools by the PDST, and expressions of interest were then collected from willing schools. 50 expressions of interest were received but only 25 schools were selected due to the available budget. The 25 schools around Ireland were chosen based on a number of factors to ensure that there was as little bias towards any one group as possible. These factors included single-sex or coeducational schools, school socio-economic status (SES), School population, sex of the teacher, and location of the school. Schools were excluded from the study if they had only one TY math class as all schools were required to have both a control and experimental group. The control group consisted of 413 participants and the experimental group consisted of 786 participants, these were grouped based on the pre-existing classes within each school. The experimental group engaged with the spatial intervention for up to 3 hours a week while the control group engaged in their normal schooling and had no contact with the intervention.

Fifty teachers undertook a tailored professional development training to prepare them to deliver the spatial skills intervention. Half of these teacher participants chose to be in the experimental group who delivered the spatial course to their students. Others, in addition to teachers who did not attend any of the spatial training, were a part of the control group. This group was "business as usual" and delivered regular mathematics classes to their students. Thirty-five teachers of the initial group completed the pre- and post- Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R) (Guay, 1976) to determine their spatial skill levels based on the rotations factor of spatial ability. This study focuses on those, more quantitative results in order to compare them with their students' spatial skill levels.

All student participants completed the PSVT:R as part of pre-testing before taking part in the intervention, and post-testing after completing the intervention. Approximately 300 student participants completed paper-based testing for all tests, while the remaining participants completed online based testing. This approach was used to determine the validity of the online PSVT:R as a measure of spatial ability, which will be investigated in future research. The online testing was conducted through the use of Google forms and could be completed on a PC, laptop, or tablet. The order in which the tests were administered was randomised for each school to account for any order bias, however all participants had equal time to complete the testing. The participants were given a time limit of 20 minutes for the PSVT:R.

Other student measures included the paper folding test, fluid reasoning test, and math competency test, while other teacher measures included classroom observations, reflective teacher logs, interviews and completing the pre- and post-anxiety test to determine their anxiety levels when working with spatial problems. These were conducted as part of a larger study which is outside the remit of this paper and so will not be investigated here.

5. RESULTS

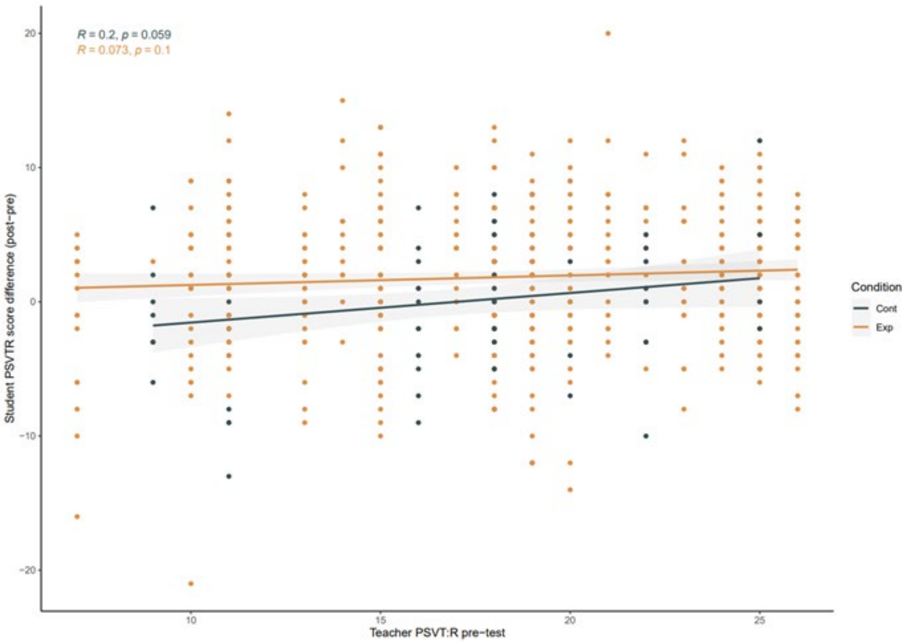
5.1. Pre-test conditions

Before discussing post-intervention impacts, it is important to understand the pre-intervention conditions. Prior to engaging with the spatial skill intervention, the control group students had a mean score of 13.29 while the experimental group students had a mean score of 13.39 on the PSVT:R. A t-test was conducted to determine if there was a significant difference that could be found between the groups ($t = -0.238$, $df = 740.12$, $p > 0.05$), this indicates that there was no significant difference between the two groups. From this we can determine that participants among the two groups scored very similarly on average. Female participants achieved a mean score of 12.56 while male participants achieved a mean score of 14.55. A t-test was conducted on these groups also ($t = -5.1291$, $df = 801.24$, $p < 0.05$), indicating a statistically significant difference between the two groups with male participants outperforming female participants by an average of 2 points on the PSVT:R. Students attending DEIS schools ('Delivering Equality of Opportunity In Schools' – this refers to schools of a lower SES in Ireland) achieved a mean score of 12.95 while students attending non-DEIS schools achieved a mean score of 13.61. A t-test was conducted to compare the groups ($t = -1.7731$, $df = 965.47$, $p = > 0.05$) and while the difference was not statistically significant, there is still a noticeable underperformance from the DEIS school participants.

5.2. RQ 1: What is the relationship between teachers' spatial ability and the extent to which their students develop their spatial skills?

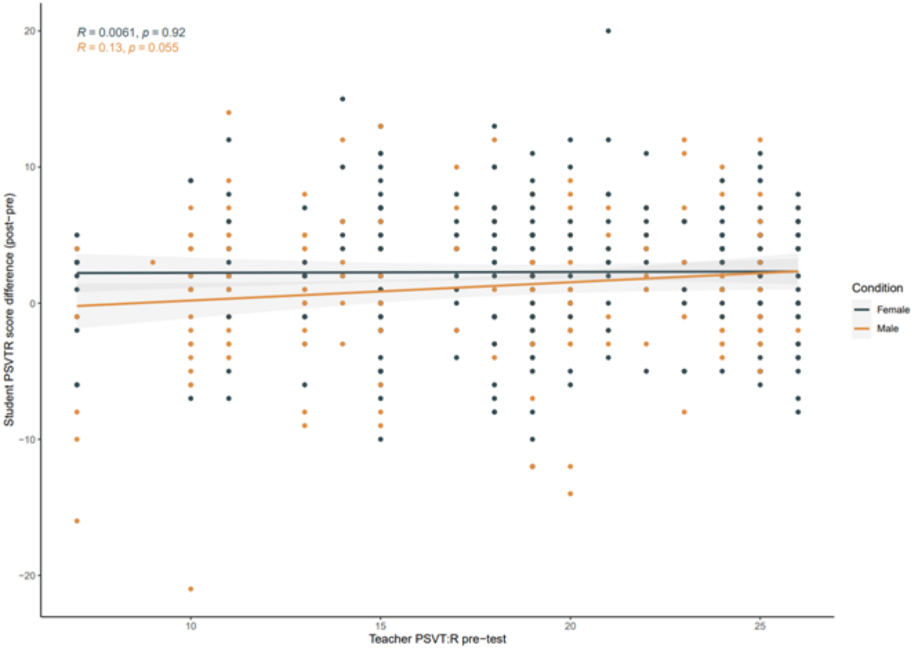
To answer this question, correlations between teacher pre-test ability and student score change on the PSVT:R were investigated. Multiple perspectives were taken while conducting these correlation analyses but due to the scope of this paper, only some of the relationships will be commented on here. The first graph (Fig. 2) shown below indicates the relationship between teacher pre-test performance and student performance change, separately for the control and experimental group. There was a weak correlation for each group, (control ($r = 0.2$, $p > 0.05$), experimental ($r = 0.073$, $p > 0.05$)), with neither being statistically significant.

Figure 2.
Correlation between teacher pre-test spatial scores and student difference in scores (post-test minus pre-test) in the PSVT:R for all participants



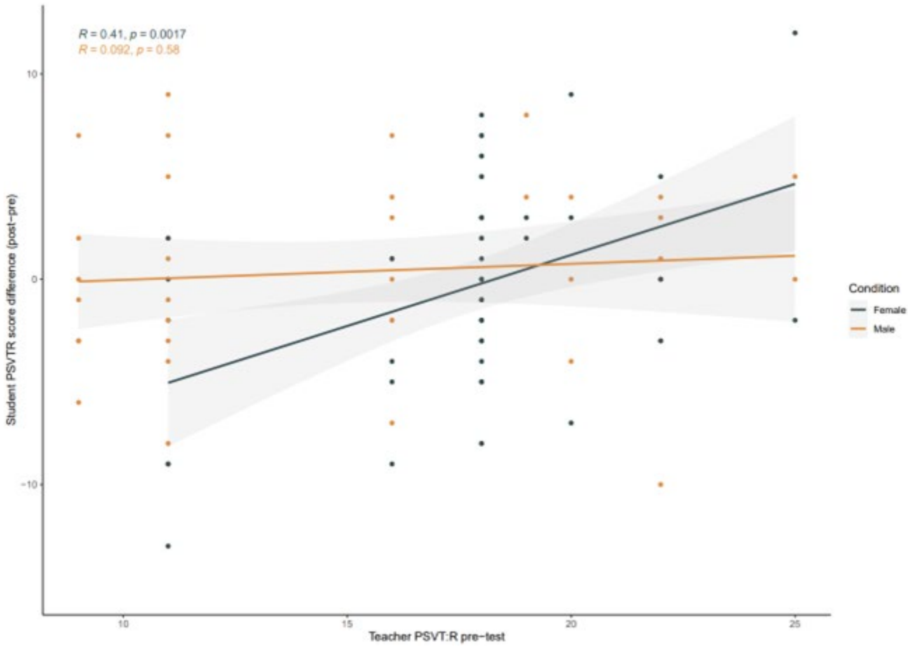
After this analysis, the authors decided to look at each group (control and experimental) in more depth. The next graph (Fig. 3) shown below describes the relationship between teacher pre-test scores and student performance change separately for male and female participants within the experimental group. As can be seen below there is a weak positive correlation for each group (female ($r = 0.0061$, $p > 0.05$) and male ($r = 0.13$, $p > 0.05$)). This suggests that teacher's initial spatial ability does not have significant impact on student performance after completing the spatial intervention.

Figure 3.
Correlation between teacher pre-test spatial scores and student difference in scores (post-test minus pre-test) in the PSVT:R. Looking at differences among genders for the experimental participants only.



The next graph, (Fig. 4) shown below, describes the relationship between teacher pre-test scores and student performance change separately for male and female participants within the control group. As can be seen there is a weak positive correlation among male participants ($r = 0.092$, $p > 0.05$) whereas there is a moderately strong correlation among female participants ($r = 0.41$, $p < 0.05$), which is also deemed statistically significant. Interestingly this result suggests that female student spatial skill development in a non-intervention setting (normal school activity) is linked to the teachers own spatial ability.

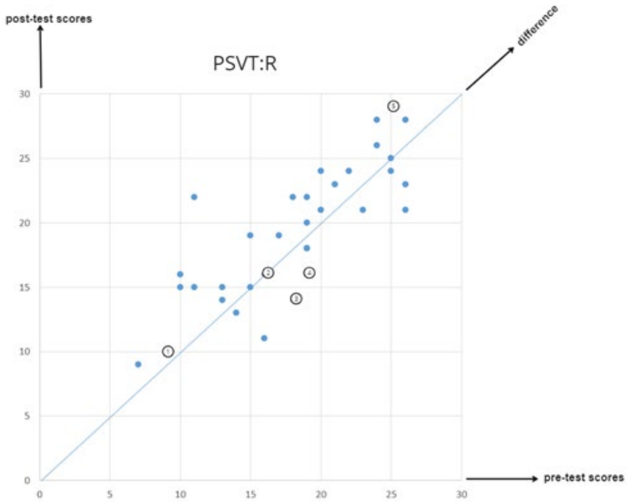
Figure 4.
Correlation between teacher pre-test spatial scores and student difference in scores (post-test minus pre-test) in the PSVT:R. Looking at differences among genders for the control participants only.



5.3. RQ 2: What is the effect of the spatial intervention on teacher spatial skill level?

Thirty-five teachers completed the pre- and post- spatial testing. Their pre-test average score was 18.1 points out of 30 and their post-test average score was 19.3 points out of 30. The scatter graph below (Fig. 5) shows teacher's change when completing the spatial testing.

Figure 5.
Scatter plot showing the relationship between teacher pre-test and post-test scores on the PSVT:R. The circles with numbers represent the teachers from the control group and the rest is from the experimental group.

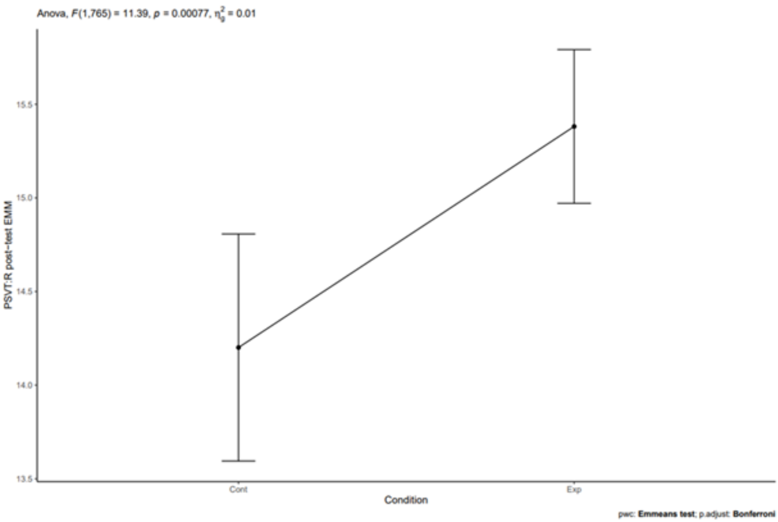


Two paired t-tests were conducted to determine if there was a statistically significant difference between pre-test and post-test performance on the PSVT:R, for control and experimental teachers separately. The control group teachers achieved a mean score of 17.4 on the pre-test and a mean score of 17 on the post-test. A paired t-test indicated ($t = 0.27869$, $df = 4$, $p > 0.05$) that there was no statistically significant difference between pre-test and post-test performance for the control group. The experimental group teachers achieved a mean score of 18.2 on the pre-test and a mean score of 19.6 on the post test, with a paired t-test ($t = -2.3408$, $df = 29$, p-value < 0.05) indicating that there is a statistically significant difference between pre-test and post-test performance for the experimental group teachers. This indicates that engaging with the PD days, along with delivering the spatial intervention has a positive impact on the spatial skills of the teacher.

5.4. RQ 3: What is the effect of the spatial intervention on student spatial skill level?

To determine the effect of the spatial intervention on student spatial skill development, post-test performance between the experimental and control groups were compared, with variances in their pre-test spatial performance being taken into account. Correlational analyses were firstly conducted to investigate if there was an association between pre and post-test performance on the spatial measure for the groups: control ($r = 0.73$, $p < 0.05$) and experimental ($r = 0.7$, $p < 0.05$). The correlations found were all statistically significant, indicating that those who performed high on the pre-test performed high on the post-test also, and vice versa for the lower achieving participants. This was also used to visually inspect the assumption of homogeneity of slopes, which was deemed to be met. An ANCOVA was performed to test the effect that the intervention had on post-test spatial performance as measured by the PSVT:R by comparing groups, while controlling for pre-test spatial scores. The numerical ANCOVA results can be seen below each related estimated (adjusted) mean plot (Fig. 6).

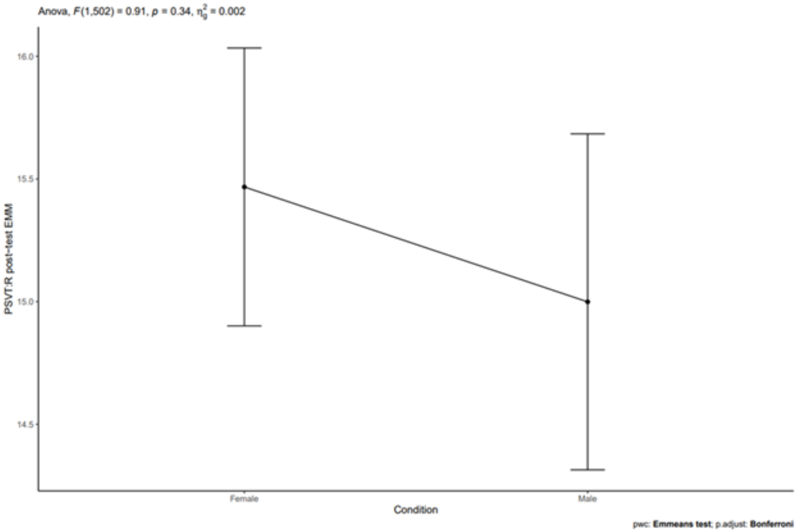
Figure 6.
Estimated (adjusted) marginal means plot for the control and experimental groups on the PSVT:R post-test after controlling for student and teacher performance on the pre-test PSVT:R



There was a significant difference in performance on the PSVT:R in the post test ($F(1,765) = 11.39$, $p < 0.05$), between the control ($M_{adjusted} = 14.2$) and experimental ($M_{adjusted} = 15.4$) groups. Therefore, evidence was found to suggest that the intervention had a positive effect on spatial test performance, having accounted for participant pre-test performance.

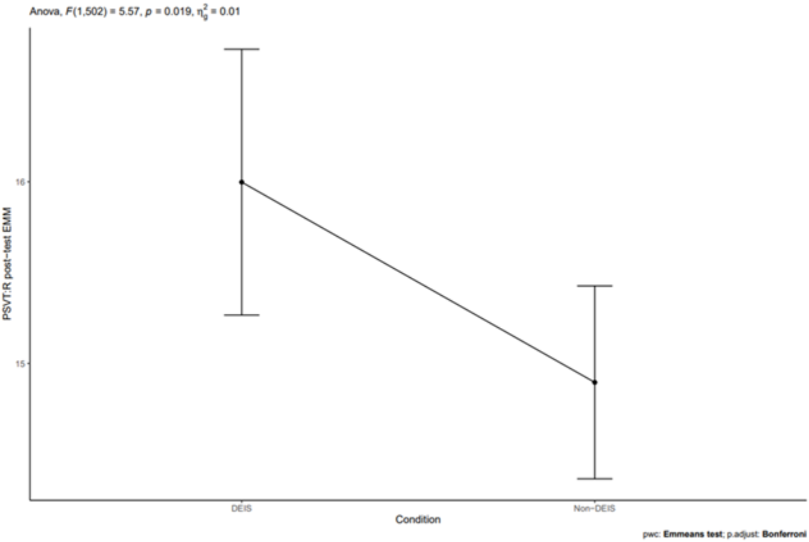
To determine the impact of gender and SES on spatial skill development only data from the experimental group was taken into account, post-test performance between the male and female groups, and DEIS and non-DEIS groups were compared, with variances in the pre-test spatial performance of both student and teachers being taken into account. Multiple correlational analyses were firstly conducted to investigate if there was an association between pre and post-test performance on the spatial measure separately for the groups: female ($r = 0.66$, $p < 0.05$), male ($r = 0.74$, $p < 0.05$), DEIS ($r = 0.69$, $p < 0.05$), and non-DIES ($r = 0.71$, $p < 0.05$). The correlations found were all statistically significant, indicating that those who performed high on the pre-test performed high on the post-test also. This was also used to visually inspect the assumption of homogeneity of slopes, which was deemed to be met. An ANCOVA was performed to test the effect that the intervention had on post-test spatial performance as measured by the PSVT:R by comparing genders (Fig. 7), and DEIS (Fig. 8), while in both cases controlling for pre-test spatial scores. The numerical ANCOVA results can be seen below each related estimated (adjusted) mean plot.

Figure 7.
Estimated (adjusted) marginal means plot for the male and female groups on the PSVT:R post-test after controlling for student and teacher performance on the pre-test PSVT:R



There was not a significant difference in performance on the PSVT:R in the post test, $F(1,502) = 0.91$, $p > 0.05$, between the female ($M_{adjusted} = 15.5$) and male ($M_{adjusted} = 15$) groups. Therefore, no evidence was found to suggest that the gender had an effect on post intervention spatial test performance.

Figure 8.
Estimated (adjusted) marginal means plot for the DEIS and non-DEIS groups on the PSVT:R post-test after controlling for student and teacher performance on the pre-test PSVT:R



There was a significant difference in performance on the PSVT:R in the post test, $F(1,502) = 5.57$, $p < 0.05$, between the DEIS ($M_{adjusted} = 16$) and non-DEIS ($M_{adjusted} = 14.9$) groups. Therefore, evidence was found to suggest that the SES had an effect on post intervention spatial test performance.

6. DISCUSSION

Our study demonstrated the impact of a spatial skills intervention on the spatial skill development of secondary level learners in Ireland. As can be seen above the experimental group outperformed the control group on the PSVT:R, with a statistically significant difference evident among the two groups. It is important to note that the control group did improve their average score on the PSVT:R but not to the same extent as the experimental group. The cause of this improvement is not known to the researchers, but it is hypothesised that this may be due to test-retest memory. When looking at the experimental group only results it is interesting to note that that the female participants outperformed the male participants, with this being opposite of the pre-test performance. A statistically significant difference between the two groups could not be found in the post-test data suggesting that taking part in this intervention supported bridging the gap between gender performance on the PSVT:R. When looking at the PSVT:R performance based on SES, it is important to note that after completing the intervention the DEIS school participants moved from underperforming in the test, to outperforming in the test, with a statistically significant difference emerging between the groups after the intervention. The reason behind this change in performance between the two groups is unclear to the researchers and further work is needed to investigate this relationship.

Although a strong correlation between teachers' spatial ability and student improvement on a spatial skills measure was not found for those taking part in the intervention, our study highlighted the impact of teacher's spatial ability on female participants spatial skills in a non-intervention environment. The reasoning behind this is unclear at this time but it is hypothesised that this may be linked to innately spatially supported teaching strategies employed by teachers of higher spatial skills. This finding is supported by previous research conducted by Krauss et al. (2008), which focused on secondary school mathematics teachers and displayed the significant impact of their mathematical content knowledge (CK) in developing efficient pedagogical content knowledge (PCK) in the area which consequently affects their students' achievements (Hill et al., 2005). This displays the importance of giving teachers enough opportunities and support to develop their own spatial thinking and reflect upon their teaching approaches since that will impact the quality of spatial education in secondary schools. Since pre-service and in-service Irish teachers are currently not being directly trained in their spatial ability development, their own abilities are still in question. The researchers suggest that spatial skills development courses may be of benefit to in-service teachers to support spatial skill development within secondary level education.

Overall, this study provides insights into the impact of an explicit spatial skills intervention on secondary level students spatial skills as measured by the PSVT:R, while also commenting on the impact of teachers' spatial ability on student development in the area. This paper also highlights the importance of supporting teachers in their own professional development to improve the quality of spatial skill development in secondary schools. Results from the study indicate the need to develop spatial skills in secondary school teachers which will later impact their ability to develop it within their students. Spatial professional development programs are a good way to achieve this with in-service teachers. When designing a new program, we need to consider many factors such as teacher's initial spatial ability levels, the selection of appropriate content, structure of the program, organizing continuing teacher support throughout the process, determining a long term vision for the intervention, collaborating with professional instructors, including diverse materials, presenting a clear picture of the practice, integrating spatial content with the existing curriculum, and thinking of ways to record teachers' instruction and provide feedback (Maquet et al., 2023).

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The Utensil and the Tool: Making Definitions Gender Inclusive

Louise Björlin Svozil, KTH Royal Institute of Technology, louisebs@kth.se

ABSTRACT

In *Thinking through technology*, Carl Mitcham puts forward his philosophical framework on technology in four aspects; objects, activities, knowledge and volition. When describing technology as objects, he presents a 'slightly modified and enlarged' list than that of Lewis Mumford, specifying 'some basic types of technology as object'. By dividing the body of technological objects into *clothes, utensils, structures, apparatus, utilities, tools, machines,* and *automata*, I argue that these divisions and descriptions of the objects will create gendered perceptions of technological objects. One example of this is the dichotomy of utensils as objects used *inside* the home, and tools as objects usually used *outside* the home. In this research paper, I intend to discuss these conceptualisations of the philosophy of technology as expressed by Carl Mitcham, arguing for more gender inclusive definitions of the utensil and the tool. Technology and masculinity have been closely intertwined for a long time and can partly be traced to women's exclusion from the labour market. Despite numerous initiatives in the past of enhancing women's attitudes, interest or will to pursue technology, the gender balance in the field has remained little affected. I argue that without an inclusive philosophy to rely on, the field of technology will continue to exclude half of the earth's population. Departing from Mitcham's philosophy of technology as object, I examine and discuss contemporary definitions of utensil and tool using a cultural lens. Finally, I endorse definitions presented by Mumford relying on function rather than culture as a way to describe technological objects.

Keywords: Philosophy of technology, Utensils, Tools, Gender, Carl Mitcham

1. INTRODUCTION

The content and orientations of technology have been imbued by male perspectives and priorities (Berner, 2003). This is an ongoing process in the co-production of gender and technology, where technology is both a source of and consequence of gender relations.

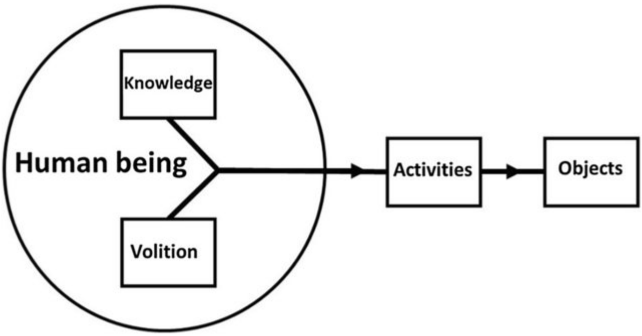
The philosophy of a field can be seen as points of departure for the field, influencing how the field evolves and will evolve over time. This makes it important for philosophers to create a ground for equality, where previous biases are critically examined. As the field of philosophy has a history of being dominated by men, the field is imbued by male experiences and perspectives (Bornemark, 2022). With this in mind, it is not surprising that the philosophy of technology is coloured by male perspectives, as both the field of philosophy as well as the field of technology are influenced by masculine ideals. However, if we continue to uncritically rely on previous body of work, we will continue to reproduce gendered ideals and not disseminate inclusive conceptualisations of technology.

In this paper, I will critically examine the definitions of two technological objects, the utensil and the tool, and show how these conceptualisations, when loaded with gendered meanings, contribute to the dichotomy and hierachisation of female and male technology. As a contribution to more sustainable definitions, I put forward existing definitions that has the potential of defining tools and utensils in accordance with their functions.

2. TECHNOLOGY AS OBJECT

Carl Mitcham has had a great impact on the philosophy of technology with his model of manifestations of technology, including technology as object, activity, knowledge and volition (Figure 1). Technology as object is considered to be the most common way of conceptualising technology (Mitcham, 1994; Svenningsson, 2020). Mitcham describes technology as objects in categories (Table 1) that he developed out of definitions originally presented by Lewis Mumford.

Figure 2.
Modes of the manifestations of technology (Mitcham, 1994).



Mumford describe elements in technology as either dynamic or static. The dynamic elements consist of tools and machines, and these are 'transforming the environment by changing shape and location of objects' (Mumford, 1934, p. 11). The static elements consist of utensils, apparatus and utilities and are used to 'effect [...] chemical transformations' (ibid, p. 11). Throughout his text, Mumford put forward the equal necessities of the two elements (Mumford, 1934).

In his, from Mumford's 'slightly modified and enlarged', list of objects, Mitcham contrasts the instruments used at home, utensils, with instruments used outside the home, tools (Mitcham, 1994, pg, 162). He further quotes Noiré (1880, as cited in Mitcham, 1994) in the division between tools and utensils:

> The tool corresponds to the creative principle. The utensil serves the preservation of life.... Thus we understand why utensils almost always are regarded as passive and named from the way in which they are produced, while tools are conceived as active and named from the actions they perform. (Mitcham, 1994, p. 163,)

Table 3.
Basic types of technology as object by Mitcham (1994).

Clothes	**artifacts for covering the human body**
Utensils	e.g., baskets, pots, spoons; storage containers and instruments of the hearth and home
Structures	houses and stationary artefact where human activity takes place
Apparatus	dye vats, containers for chemical or physical processes
Utilities	paths, roads, reservoirs, electric power networks
Tools	instruments operated manually that act to move or transform the material world, usually outside the home (contrast household utensils); typically, implements a worker uses to perform work, although there are certainly tools of communication and scholarship (paper and pen) as such
Machines	tools that do not require human energy input, but human direction
Automata	machines neither requiring human energy nor input

2.1. Contemporary definitions of utensils and tools

As ideals change, so do the descriptions and meanings of concepts. In a perhaps more contemporary definition of utensils and tools, these are differentiated by the level of skill they require for use (Merriam-Webster.com Dictionary, 2023). Accordingly, Utensil 'applies to a device used in domestic work or some routine unskilled activity', whereas Tool 'suggests an implement adapted to facilitate a definite kind or stage of work and suggests the need of skill more strongly than implement' (Merriam-Webster.com Dictionary, 2023). This distinction of tools requiring more skill than utensils begins to arrange the two concepts in a hierarchical order.

Another contemporary description of the utensil-tool dichotomy found in a website on lifestyle, defines a utensil as something that serves a purpose in the kitchen, whereas a tool is used to accomplish a goal elsewhere:

> Unlike tools, utensils serve a specific purpose in the kitchen. In addition to using her hands when preparing food, a cook also uses utensils such as a whisk or paring knives. The purpose for tools includes helping a person accomplish a goal, whether he's working in a garden, constructing a building or creating a business. (Sewell, 2011, para. 3)

In a language column in a Swedish newspaper, Strömquist makes an effort in trying to detangle utensils and tools using a definition from Nusvensk ordbok: 'The difference between utensils[3] and tools[4] is that with a tool something is made, with a utensil something is done' (Strömquist, 2004, para. 2, author's translation). Further, Strömquist either suggests that area of use or the nature of the use is defining the instrument as either utensil or tool. Finally, Strömquist conclude the interchangeability of the concepts.

Consulting a textbook used in technology secondary education in Sweden, the tool concept has a different meaning (Karlsson & Brink, 2017). In a section called 'Technology solves small problems', the instruments in the kitchen are described as tools, referring to knifes, containers and bowls. The term utensil is not used.

3. THE PRINCIPLES OF THE GENDER SYSTEM

Discursive formations in our language are formed in accordance with cultural and historical settings and carry meaning that has consequences for power relations in our society (Fairclough, 2009). The power relations between women and men, the gender system, are described by Hirdman (1988) as two principles, the separating and the hierarchising. The separating principle is structuring places, occupations, and qualities into different categories. The hierarchising principle is ordering the male as norm. The separation principle can be seen in perceptions and expectations of how a woman or a man should be.

In the industrial and commercial society that has evolved throughout the last centuries, the social division of work can be described as 'labour' and 'home' (Connell, 2009). The labour sphere is described as the sphere for paid work and production for the market and culturally defined as a man's world. The home sphere is described as the sphere of unpaid work and culturally defined as a woman's world (ibid).

In the social construction of women and men as separate and opposite, certain qualities have been put forward as differentiating the genders. For example, in discussions on the biological differences between women and men, there are arguments that the biological differences are manifested in qualities such as men being faster and stronger, technically skilled, aggressive, rational and women as nurturing and intuitive (Connell, 2009). These constructions can also be seen when looking at synonyms for or definitions of 'feminine' and 'masculine'. Synonyms for 'feminine' are soft, delicate, gentle, tender, graceful, refined, modest (Oxford Languages, 2023). The Wikipedia site for 'masculinity' presents the quality as 'Traits traditionally viewed as masculine in Western society include strength, courage, independence, leadership, and assertiveness' ('Masculinity', 2023).

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[3] translated from *redskap*

[4] translated from *verktyg*

I will in the following section explore how these constructions imbue the definitions of utensil and tool.

4. THE UTENSIL AND THE TOOL AS GENDERED CONCEPTS

The various definitions of utensil and tool can be seen as attempts to structure technological objects. To create frameworks and definitions is of course essential for creating an understanding. However, as many of the definitions of utensil and tool are constructed and contrasted to each other, this creates implications of the instruments and their users. By referring to utensils as used inside the home, requiring less skill and passive, and tools as used outside the home, performing skilled activities and active, the two objects are separated and contrasted to each other. This orders tools on top of utensils in the hierarchy of technological objects (Table 2).

Table 4.
The utensil-tool dichotomy

Utensil	Tool	Source
passive	active	Ludwig Noiré (1880)
preservation of life	creative principle	Ludwig Noiré (1880)
static	dynamic	Lewis Mumford (1934)
inside the home - domestic sphere	outside the home - public sphere	Mitcham (1994)
something is performed	something is built	Strömquist (2004)
-	solves small problems	Karlsson & Brink (2017)
unskilled activity	skilled activity	Merriam-Webster.com Dictionary (2023)
serve a specific purpose	accomplish a goal	Sewell (2011) at Hunker.com

4.1. The inside-outside home dichotomy

As women have traditionally (in the western world) been occupying the home sphere, Mitcham establishes a connection between the utensil and the woman by referring to utensils as 'instruments of the hearth and home'. The work in the home has also had less status, possibly shaping the perception of the utensil requiring less skill for use than equipment used in labour work.

The website on lifestyle, Hunker.com (Sewell, 2011), contrasts utensils as serving a specific purpose in the kitchen, and tools as helping the user accomplishing a goal elsewhere. Similarly, to Mitcham, the website describes the instruments occupying different spheres, the kitchen and elsewhere. Moreover, by giving the users in the description of the utensils and tools different genders, 'hers' and 'his', the separation is reinforced. Furthermore, the description of utensils as serving a specific purpose does not acknowledge the wide application of a whisk. A whisk can stir, whip and mash just as a drill can make a hole in wood, concrete, and metal.

If utensils are defined as instruments used inside the home, it is hard to categorise objects that are found inside the home but show similarities with other categories. Apparatus, for example, has similarities with utensils in that both describe containers. The difference is, according to Mitcham

(1994), that containers of the apparatus type is used for 'physical or chemical processes'. However, with Mitcham's categorisation, a container used inside the home for physical or chemical processes is a utensil. Again, this division connects apparatus with labour work and utensils with the work done in the home.

As technology often is defined in relation to tools and machines, the inclusion of utensils, to include technological objects from the female spere, could some time ago have seemed like an attempt to widen the concept of technological objects. However, to put all technological objects handled in the home in one category is contributing to the separation principle by categorising all instruments handled in the female sphere as utensils and those handled in the male sphere as tools. It is the division relying on the where, inside or outside the home, i.e., its cultural context and with whom this is connected, that limits the possibilities of creating inclusive descriptions of technology as objects, or descriptions that do not reproduce gender norms. By connecting the utensil to the home, the sphere of unpaid work, and the tool to paid work, the sphere of labour, this loads the objects with different status. Moreover, as the definitions of utensils and tools continue to contrast the two to each other, especially using value laden terms, the cultural reproduction is at work.

4.2. The passive-active dichotomy

Research is commonly coloured by contemporary ideologies (Ah-King, 2012). Noiré's (1880, cited in Mitcham, 1994) dichotomous descriptions of utensils as 'passive' and serving the 'preservation of life', and tools as 'active' and corresponding to the 'creative principle' is drawing on, for that time, contemporary ideals of women and men.

A spoon is one of the examples that Mitcham categorises as a utensil. As a spoon is usually found in 'the hearth and home', this might be the definition Mitcham is relying on in this categorisation. However, as a spoon can 'act to transform or move the material world' by stirring or scooping up liquid or fine-grained materials, it could also be a tool with Mitcham's definition.

4.3. The preserving-creating dichotomy

Ideals of men as creators and women as nurturers can be seen in the separation of 'creative principle' and 'preservation of life'. If considering the tasks to build a house and to prepare a meal, these can both be considered to preserve life although the former uses tools, and the latter uses utensils, according to Mitcham (1994, p. 162).

4.4. The unskilled-skilled dichotomy

To say that tools require more skill for using than utensils do, like Merriam-Webster.com Dictionary (2023) stated, is a misconception. As many people eat roughly three times a day, there are many opportunities to practice the use of a knife. In an average home, the drill is not used daily, thus the opportunities given to practice the use of the drill are much fewer. The lack of practice could give the impression that it requires more skill to use a drill than a knife. However, it requires more skill to fillet a fish than it does to drill a hole in a wooden wall (without electric cabling in the wall).

4.5. The tool in the kitchen

In the technology textbook (Karlsson & Brink, 2017), instruments used in the kitchen are called tools. The use of the word tool, instead of utensil, for instruments used in the kitchen, can be seen as a way to rise the status of the work done in the kitchen. While other sources compare the two concepts to each other and describing tools as the more sophisticated, the textbook, directed to young people learning technological concepts, attempt to give the work done in the kitchen the same status as work done outside the home.

5. FUNCTIONAL INSTEAD OF CULTURAL DESCRIPTIONS

If we want to achieve a more equal access to technology and technological objects, we need to make sure the language we use supports that intent. When technological objects are classified and defined using cultural meanings, they become loaded with values on who is the natural user and the quality of the work that user performs. Instead, the aim should be to raise definitions of utensils and tools that are clear and that do not connect the concepts to cultural contexts reproducing gendered structures. Value loaded words should also be avoided when describing technological objects as they contribute to hierarchically ordering the objects and its users. For example, words like 'unskilled' degrades the user of such objects.

One way of avoiding reproducing gender in the conceptualisations of utensils and tools could be to use more gender-neutral words like instruments or devices as this category includes utensils as well as tools. As there are a lot of similarities between the instruments that Mitcham has classified as utensils and tools, it can be difficult at first sight to tell them apart. A knife and a saw perform the same task, to cut or slice items, although used in different spaces of our everyday life. A fork and a hayfork, used for pinching, poking or stabbing things. A spoon and a spade are both used for moving 'the material world' from one place to another. To discuss these similarities, we can instead raise the likenesses, which is a powerful act to change the dynamics of the gender system (Hirdman, 1988).

As I have shown, both Mitcham's definitions and contemporary definitions of technological objects rely on cultural descriptions. However, to discard 'utensil' and 'tool', i.e., suggest their dismission, might neither be possible nor fruitful for the discussion on the philosophy of technology. Technology is intertwined with our culture, thus culture will find its way into the definitions. But if we in our definitions lean on the descriptions focusing on the functionalities of the technological objects, we can get closer to accurate definitions without soiling them with cultural biases.

A framework suitable to build these definitions from is that by Mumford. Dividing technological objects in the rather neutral categories 'static' and 'dynamic', the definition of tools as 'transforming the environment by changing shape and location of objects' and utensils as 'effect [...] chemical transformations' can be built upon (Table 3). Previously mentioned definitions can be added to pinpoint the concepts. For tool to 'fulfill a goal' (Merriam-Webster.com Dictionary, 2023) or 'act to move or transform the material world' (Mitcham, 1994) and utensil - to 'serve a purpose' (discarding 'specific', Merriam-Webster.com Dictionary, 2023). In that case, the definition of utensil is similar to Mitcham's apparatus just like Mumford intended when he categorised them both as 'static', but without specifying where they are used.

Table 5.
Functional definitions of utensil and tool

Utensil	Tool	Source
static	dynamic	Mumford (1934)
transforming the environment by changing shape and location of objects	effect chemical transformations	Mumford (1934)
act to move or transform the material world		Mitcham (1994)
fulfill a goal	serve a purpose	(Merriam-Webster.com Dictionary, 2023)

In this way a kitchen knife is a tool in the sense that it fulfills the goal of chopping vegetables; it transforms the vegetables from one shape to another. Similarly, a saw is a tool, as it fulfills the goal of cutting off a plank to the desired length. It transforms the plank from one length to another (shorter). A whisk is a tool, as it fulfills the goal of whipping, stirring or mashing food. It transforms the cream from one texture to another, moves the ingredients of the sauce from being separated to united, and mashes the whole potatoes to small grains or even down to starch chains.

A cutting board would be a utensil in the sense that it serves the purpose of protecting the kitchen countertop from the knife and protecting the knife from getting blunt. With a cutting board on its own, it would be difficult to achieve any kind of substantial goal (if perhaps it is used outside its scope to smash a nut, but in that case, it would better be defined as a tool). A clamp is a utensil, as it serves the purpose of holding the material in place while doing a job on it, and when holding together pieces of material in order for the glue (the tool!) to fulfill the goal of sticking the pieces together. A pin is a utensil, as it holds the fabric together while sewing. A paint tray is a utensil, as it serves the purpose of accommodating the paint for the roller to be dipped in. And so on.

Of course, in this endeavour, we come across instruments that do not fit in either category. We look at the spirit level, the measuring tape, and the volume measuring kit, and think: What is this? On their own, they are not enough to fulfill a goal if the goal is not simply to measure. Nor do they act to move or transform the material world (if the volume measure is not used for scoping, in that case it is a tool). These are all concerned with the quality of the goal. We aim for putting up a straight shelf, not a shelf where things on it come rolling off. We aim for sewing a close-fitting dress, not a dress of any size. We aim for baking a delicious and fluffy cake, not a burned one. Without their help, we would be able to achieve the goal of a set up shelf, a dress, and a cake, but with questionable quality.

6. CONCLUSION

Although philosophers of technology do not have the almighty power of deciding how languages are to be used, we can critically examine our own use of technological concepts and discuss definitions as we aim to lay out a solid foundation for our field to grow in, for all genders.

This is only a small part of the cultural conceptions of technology (Wajcman, 2010). It could be important for technology educators to be aware of the various conceptions of utensil and tool, and to be able to critically examine these definitions to not support further gendering of technological items. Definitions relying more on function than on culture could be a way forward in nuancing technological objects without loading them with gendered meanings.

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How do Swedish Technology Teachers Assess Programming Education in Grade 4-6?

Eva-Lena Bjursten, Mälardalen University, eva-lena.bjursten@mdu.se
Lena Gumaelius, KTH Royal Institute of Technology, lenagu@kth.se

ABSTRACT

This study examines Swedish teachers' teaching and assessment practices in programming education for students in grades 4-6, with a focus on the technology subject. It investigates whether existing governing documents provide sufficient guidance for effective teaching and assessment in programming, particularly regarding Pedagogical Content Knowledge (PCK). The study addresses challenges faced by teachers, including limited training and a lack of instructional guidelines, stressing the importance of bridging this gap to support effective programming instruction and assessment. It explores assessment practices in programming within the technology subject, referring to previous studies that identify various approaches. The discussion includes product and process criteria for assessing programming tasks and emphasizes the need for clearer links between programming assessment and core technology content. The methodology involves semi-structured interviews with experienced teachers who taught programming prior to its inclusion in the curriculum. Analyzing the interview data helps examine alignment between teachers' assessment practices and governing documents. Results and discussion focus on one teacher, Camilla, with six years of programming teaching experience. It describes how Camilla facilitates curriculum goals and aligns assessments with grading criteria. The article also summarizes specific areas assessed in programming education and compares Camilla's criteria with essential content knowledge from previous studies. Based on the findings, the study concludes that while Camilla demonstrates comprehensive understanding of assessing programming knowledge, improvements are necessary in primary school programming education in Sweden. The existing governing documents inadequately support effective programming instruction, particularly in terms of content knowledge. It suggests identifying key characteristics of quality programming education at each stage of compulsory schooling and engaging in discussions to establish a strong educational foundation.

Keywords: Computer programming, PCK, assessment, teacher education, professional development

1. INTRODUCTION

In today's technology-driven world, programming education has become crucial for preparing students for the digital age. In Sweden, programming was introduced as new content in technology and mathematics subjects in compulsory school (Statens Skolverk, 2017). However, despite the curriculum update in 2022, the content and approach to teaching programming were not significantly altered (Statens Skolverk, 2022b). Nevertheless, many teachers face challenges in teaching and assessing this relatively new content, often due to limited training in the field (Vinnervik, 2020). Additionally, there is a lack of instructional guidelines available to assist teachers in approaching this relatively new content (Nordén, Heintz, Mannila, Parnes, & Regnell, 2017). Bridging this gap is essential to support teachers in effectively teaching and assessing programming. This article aims to explore the teaching and assessment practices of Swedish teachers in programming education, specifically focusing on the technology subject for students in grades 4-6, with a particular emphasis on Pedagogical Content Knowledge (PCK) in programming.

Assessment in programming within the technology subject has been previously studied, but different approaches have been taken. Björklund and Nordlöf (2021) identified two types of criteria used by teachers in assessing programming: product criteria and process criteria. Their findings suggest that process criteria, including investigative work, inventiveness, ability to use models, and capacity for self-assessment, could be useful in assessing students struggling with programming tasks. On the other hand, Mannila, Heintz, Kjällander and Åkerfeldt (2020) aimed to develop a comprehensive assessment framework for programming education across different grades. Their pilot study highlighted the effectiveness of combining multiple-choice and open-ended skills questions to assess students' abilities and identify misconceptions. However, there remains a need to establish clearer links between programming assessment and the core content of technology. Additionally, previous studies have indicated challenges in articulating the assessment of programming tasks, emphasizing the importance of assessing the entire process from idea to final product (Bjursten, Hartell, & Gumaelius, 2022).

Teaching and assessment are intricately linked, collectively shaping the learning experience. By examining how teachers assess their students' programming abilities, we can gain insights into the perceived importance and challenges associated with programming education. In this study, we delve into the assessment practices of an experienced teacher who taught programming even before its official inclusion in the curriculum. Through an interview with this teacher, we aim to investigate whether the existing governing documents provide sufficient guidance for teachers to effectively teach and assess their students in programming. The research question that forms the basis of this study is as follows:

Do the existing governing documents provide sufficient guidance for teachers to teach and assess their students in programming?

1.1. PCK in programming

The teacher's ability to effectively teach programming is often referred to as Pedagogical Content Knowledge (PCK) in the literature (Shulman, 1987, 2013). While PCK is well-established in various school subjects (Doyle, Seery, Gumaelius, Canty, & Hartell, 2019), its clear definition in programming is still evolving (Hubbard, 2018). Saeli, Perrenet, M.G. Jochems and Zwaneveld (2010) conducted a study defining desirable PCK in programming for secondary school and higher education, which serves as a foundation for this current study focusing on programming education in grades 4-6 of compulsory schools. It is important to acknowledge that the concepts and approaches designed for higher education may not be directly applicable or suitable for younger students. By examining an experienced programming teacher's assessment practices and their alignment with the governing documents, as well as comparing them to the specific context of programming from Saeli's study, this investigation aims to provide valuable insights into the knowledge and skills necessary for effectively teaching programming concepts in this age group.

1.2. Programming in Steering Documents in Swedish Schools

The inclusion of programming in the curriculum of Swedish schools is reflected in the steering documents that outline the objectives and guidelines for the technology subject. According to the syllabus, one of the core contents is the ability to program an object and control their own constructions or other objects through programming. This directive is stated under the section titled 'Working methods for developing technical solutions' (Statens Skolverk, 2022b, p. 259).

Furthermore, the syllabus is further supplemented by material on digitalization from the national education agency (Statens Skolverk, 2022a, pp. 9-10), which emphasizes that programming should be approached from a broader perspective beyond mere coding. This additional material highlights the need to consider programming as an integral part of digitalization, encompassing various aspects beyond the technical aspects of coding. However, despite the curriculum update in 2022, the grading criteria and goals were not significantly altered (Statens Skolverk, 2022b), resulting, again, in programming not being explicitly mentioned in the grading criteria and goals. As these steering documents play a crucial role in providing guidance to teaching, it is important to examine whether the existing documents offer sufficient support and clarity for teachers in assessing their students' abilities programming in technology.

2. METHOD

The first author conducted semi-structured interviews with seven participants. All participants had previously participated in a study that included 14 experienced technology teachers in grades 4-6 taken place in 2018 and 2019 and were willing to participate again. The participants had been teaching programming before it became part of the curriculum, hence they are experienced teachers in programming in technology (Bjursten, Nilsson, & Gumaelius, 2022).

The aim of the interviews was both to follow up the data from a previous study and to focus even more on how assessment in programming is conducted.

The interviews were conducted in Zoom and lasted approximately one hour. The interviews were recorded on Zoom with the participants' consent and transcribed verbatim for analysis.

The present article provides an example of one of the seven teachers, Camilla, in which the teacher's assessment practices are described. Camilla has been teaching for 28 years and has been teaching programming in technology for the past six years. Her motivations stem from both the need to stay updated with the curriculum and her genuine passion for digital technology. This teacher was selected randomly from the material. The interview data was thematized according to how the teacher expressed assessment based on the goals and grading criteria outlined in the curriculum. The first and second authors then compared and discussed the findings to reach a consensus.

In the analyzing phase, the themes were compared with the study focuses on how the teacher's PCK aligns with the big ideas of programming as described in the literature Saeli et al. (2010).

3. RESULT AND DISCUSSION

This section comprises three subsections: ‘Overview of the teaching and assessment practice’, ‘How the teacher aligns the assessment process to the grading criteria curriculum, and ‘Summary of what is assessed in programming in the subject technology’. These subsections provide a comprehensive analysis of the teaching methods, their alignment with the assessment process, and a summary of the specific areas assessed in programming education.

3.1. Overview of the teaching and assessment practice

In order to gain insight into Camilla's teaching practices and methods to promote the development of skills in her students, we first asked how she facilitates the acquisition of the three goals described in the technology syllabus in her teaching of programming.

When discussing the first goal, the capacity to carry out technological development and construction work (Statens Skolverk, 2022b), she mentions that they have built a LEGO robot, which involves both mechanical construction and programming. They need to follow instructions and troubleshoot if the robot doesn't function as intended.

For the second goal, knowledge of technical solutions and how their components interact to achieve purposefulness and functionality (Statens Skolverk, 2022b). In the context of programming, Camilla highlights the importance of synchronizing different parts of the program and understanding their functionality. She mentions examples like pedometers and timers, where it is essential to differentiate between them and ensure they work together without conflicts.

The third goal in the curriculum is to reflect on different choices of technical solutions and their consequences, as well as how technology changes over time (Statens Skolverk, 2022b). Here Camilla provides an example of working with smartwatches and comparing them to analog wristwatches, where students learn to program Micro:bit devices to perform multiple functions. They explore the advantages and disadvantages of different technical solutions and consider why it might be interesting to add additional features or functionality. Overall, Camilla emphasizes the importance of hands-on construction, programming, and critical thinking skills in relation to technology education.

3.2. How the teacher aligns the assessment process to the grading criteria curriculum

The grading criteria of the Swedish curriculum for grade A at the end of Year 6 are in line with the goals which means that it is not necessary to separate when to assess the goal or the grading criteria. They include the ability to provide examples of technical solutions and describe their advantages, disadvantages, and how they have evolved over time. Also, the students are expected to investigate technical solutions and demonstrate an understanding of how different parts interact to achieve effectiveness and functionality. Additionally, they should be able to carry out simple technical development and construction work, formulating and selecting appropriate action options and documenting their solutions clearly (Statens Skolverk, 2022b).

During the interview, Camilla discussed her approach to supporting students in their learning process. She emphasized the importance of striking a balance between independent work and seeking guidance. Camilla clarified that the level of independence demonstrated by students influences their grades. The more independently students work and the fewer questions they need to ask, the higher their grade tends to be. However, she also made it clear that asking questions and seeking advice are important aspects of the learning process. Camilla stressed that it is through questioning and guidance that students can expand their understanding and knowledge.

Camilla further explained her assessment criteria for programming tasks using Micro:bit. She differentiated between different levels of proficiency based on the complexity of students' programs. The use of ready-made blocks in Micro:bit indicated a basic level of proficiency, while the inclusion of additional variables and functions elevated the work to higher levels. Camilla emphasized the importance of understanding the idea behind the program and encouraged students to experiment and revise their ideas, even if the program was not flawless.

She highlighted the significance of students formulating their own ideas and taking initiative in their work. Students who demonstrate a clear idea for a technical solution and can articulate it effectively are more likely to achieve higher grades. Camilla mentioned examples such as creating a clock or a step counter with specific functions, where students need to consider the different parts and actions required for the solution to work. The ability to demonstrate a thoughtful approach and effectively communicate their ideas in the program itself is considered when assessing students' work.

During the interview, Camilla shared her insights into the factors that contribute to higher grades in the context of technical development and construction work. She emphasized that while independent work and problem-solving skills are valued, asking for assistance and seeking guidance are not discouraged. Camilla recognized that learning occurs through questioning and encouraged students to ask for help when needed.

Camilla also mentioned that the length or complexity of a program does not necessarily determine the grade. Instead, she emphasized the importance of clarity, understanding, and the intention behind the program. As long as the core idea is functional and the purpose is evident, the program can meet the grading criteria.

3.3. Summary of what is assessed in programming in the subject technology

Overall, the interview with Camilla highlighted her approach to meeting the goals and grading criteria of the curriculum. Her instructional strategies emphasized critical thinking, independent problem-solving, collaboration, and reflection. By engaging students in practical activities, encouraging experimentation, and providing guidance, when necessary, Camilla aimed to facilitate their development of technical knowledge, construction skills, and proficiency in programming.

In order to gain insight into how effective Camilla's assessment method is particularly in relation to essential content knowledge (CK), we have conducted a mapping exercise to determine how Camilla's assessment criteria align with the essential content knowledge identified by Saeli et al. (2010).

The resulting table illustrates that Camilla predominantly incorporates four of the eleven concepts and fundamental principles put forth by Saeli et al. (2010). Furthermore, while ‘Procedures’ are not explicitly mentioned, it is evident that she understands the concept based on her acknowledgement that a decomposed program is easier to debug, indicating familiarity with the concept without explicitly using its name. For example, the following interview extract serves as an illustration of Camilla's incorporation of some of these significant ideas:

> I usually say that the program should have three parts for a C, but there are no specific length requirements [length of the programming code], they [the functions/modules/parallel processes] just shouldn't clash with each other. And then, for the next level, there should be an additional variable. And at the A level, I usually require them to have a function of some kind... that calls another function. Alternatively, they can have multiple different variables. That can also compensate. So, I have found some sort of model for that, and I've managed to come up with student examples for each way so that I can show the students in advance what it should look like. I usually don't have a strict requirement for it [the program] to work perfectly, as long as one part works and I can understand the idea behind the others, it can be enough.

Table 1.
Content Knowledge according to Saeli et al. (2010); Saeli, Perrenet, M.G. Jochems and Zwaneveld (2012)

Programming concepts	Camilla
Control structures: Loops, conditions and sequential	(X)
Functions, procedures, methods	X
Algorithms	
Variables (and Constants)	X
Parameters	
Data structure	
Decomposition	X
Reusability	
Arrays	
Logical thinking	
Formal language grammar and syntax	

However, it is worth noting that certain foundational programming concepts are absent from Camilla's student assessments. Notably, the control structure loop is not explicitly addressed. This oversight potentially implies that students may lack crucial components essential for their future progression in programming. Without acquiring the necessary foundational knowledge, advancing to more complex stages of their programming education become significantly more challenging. An analogy can be drawn to the teaching of mathematics, wherein omitting one of the four fundamental counting methods hinders students when confronted with intricate problem-solving tasks. Similarly, the omission of a key concept like 'loop' at an early stage may render students ill-equipped to tackle and comprehend more intricate programming assignments. These observations find support in previous literature, further reinforcing this argument. However, since secondary and higher education teachers are included in Saeli et al. (2010), it is not clear which concepts of the above mentioned still apply to students in grades 4-6. Additionally, as an example, when utilizing a visual programming language with fixed syntax, it becomes necessary to explore alternative methods for evaluating 'Formal language grammar and syntax' since the syntax cannot be modified.

4. CONCLUSION

In conclusion, the teacher Camilla possesses a strong sense of confidence in her capacity as a programming instructor and demonstrates a comprehensive understanding of how to assess her students' programming knowledge. However, our findings highlight the need for improvements in programming education in primary schools in Sweden. The current descriptions and guidelines provided by governing documents are insufficient in supporting teachers to deliver effective programming instruction when it comes to content knowledge. To ensure a comprehensive and progressive approach to programming education, it is crucial to identify the key characteristics (e.g., 'big ideas') of good programming education in technology in each of the stages in compulsory schools. By engaging in discussions and exploring the relevant knowledge and skills required for programming at an early age, we can lay a strong foundation for students' educational advancement. This not only ensures compliance with legal requirements but also facilitates their overall learning and development.

Consequently, the next logical step could be to conduct a survey among experienced and accomplished teachers to gather their perspectives on the key elements (CK) that characterize good programming education in primary schools in technology. That would help identify the specific programming content experienced technology teachers use in primary school years 4-6 and thus contribute to the most effective in teaching programming to primary school students. By gaining insights from experienced teachers, we can enhance the quality of programming education in technology and provide valuable guidance for curriculum development and teacher training in this field.

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Developing Technology Students' Hierarchical Thinking During Iterative Processes of Designing Through Sketching Activities

Nicolaas Blom, University of Limerick, nicolaas.blom@ul.ie
Donal Canty, University of Limerick, donal.canty@ul.ie
Diarmaid Lane, University of Limerick, diarmaid.lane@ul.ie
Sean O'Connor, University of Limerick, sean.oconnor@ul.ie

ABSTRACT

The development of students' hierarchical thinking during iterative processes of designing through sketching activities is a crucial part of design education as it supports the connection between students' design intentions and its material embodiment. To this end, this paper discusses how different types of sketching activities can facilitate the development of hierarchical thinking in design activities. In this paper, we define hierarchical thinking as the ability to move between abstract and concrete representations through varying levels of specificity as well as the journey from global to specific representations. Doing this, we explore how using different sketching activities can allow students to explore a range of design intentions and physical embodiments at different levels of abstraction and detail. The paper also discusses how the idea of hierarchical thinking can support design educators to teach students to engage with their design processes more productively on a need-to-know basis. By teaching students to move between different levels of abstraction and detail effectively, teachers can support students to develop a more nuanced and comprehensive understanding of their designerly processes. Overall, this paper highlights the importance of modelling through sketching and hierarchical thinking in design education and practice.

Keywords: Hierarchical Thinking, Design Representations, Iterative Processes of Designing

1. INTRODUCTION

One of the main aims of design and technology education is to foster pupils' ability to engage in complex, real-world designing. To do this, pupils engage in authentic, collaborative design-based learning projects in which they are challenged to identify and address design challenges. However, these design challenges are often presented in a prescriptive manner, following a linear sequence of design activities, that often deny pupils the opportunity to explore complexity by connecting given problem scenarios, and solutions in a fit-for-purpose and intentional manner (Haupt, 2018). In addition, novice designers might lack the experience of connecting design 'problems' with suitable or fit-for-purpose design solutions. Practical encounters of what happens in technology classrooms reveal that pupils often engage in fragmented and disjointed activities where their sketches or 3D models have limited conceptual connection with the bigger socio-technological issues articulated in the scenarios they are supposed to address (Haupt, 2018). Further to this, instruction on using design representations to support designing is often neglected at the expense of teaching students to document design processes. We believe that the obstacles posed by these challenges make it difficult for design and technology educators to guide students in linking their design goals with the tangible realization of their concepts.

Currently, research on teaching how to foster design capability in a manner that allows pupils to develop coherence between material solutions, design problems and design intentions, seem limited (Haupt, 2018). This limitation consequently results in fostering misconceptions regarding the intentional and integrated nature of designing. As such, there is a need to develop tools that can support the ways in which designers engage in designing, while maintaining coherence of scenario, intentions, challenges, and solutions. To this end, this paper presents a teaching tool through which designers' hierarchical thinking can be fostered. To create this framework, we draw upon various design education ideas, including iterative processes of designing (Kimbell & Stables, 2008), hierarchical thinking (Haupt, 2018), and the creation of design representations (Pei & Self, 2022).

In this paper, we present a novel teaching tool for using sketching activities to develop design and technology students' hierarchical thinking. This framework explains how the intentional use of different types of sketches give rise to coherent and connected design ideas. This framework can support teachers of design education to enhance their understanding and practice related to the role of sketching during processes of designing. This framework is important for teachers of design, who can use students' external representations to provide feedback, scaffold future action and reflection activities, or guide students to available tools and materials to examine and realise their design ideas.

2. LITERATURE REVIEW

2.1. Hierarchical thinking during iterative designing

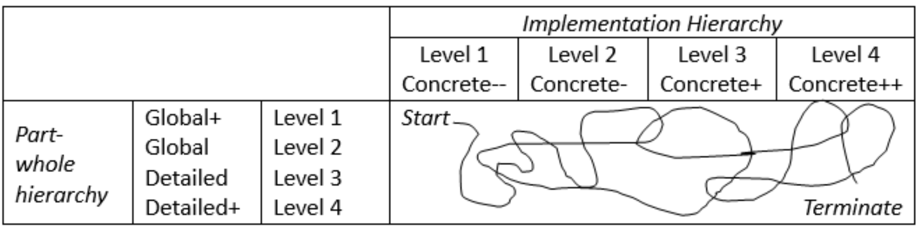
During the iterative design process, hierarchical thinking plays a crucial role in supporting students' ability to maintain coherence of design intentions with related material embodiments. Historically, hierarchical thinking originated from Hierarchy Theory, which is concerned with how humans approach complex problems (Allen & Starr, 2017). This approach consists of viewing problems and their solutions in a set of interrelated levels. As such, hierarchical thinking indicates a relationship between the starting level of thinking and its following levels (Medland, 2007). When applied to design cognition, this implies that designers progress through processes of designing by engaging in various interrelated levels of thinking that could be distinguished from each other based on the content of designers' thoughts as well as the varying levels of specificity revealed in their external representations (Goel, 2014; Haupt, 2018; Kamffer, 2019).

Over the past 20 years, various models have emerged in the literature explaining how professional designers engage in hierarchical thinking. For example, Gero's (1998) Function Behaviour Structure (FBS) framework; Vermaas's (2009) Model of Conceptual layering of technical devices and Haupt's (2018) cognitive tool for guiding coherent decision making. These frameworks primarily focus on what designers think about during designing, including their design goals, requirements, functionality, behaviour and physicality of the artefact that they are designing. However, a notable omission from these hierarchical thinking descriptions is an examination of how design representations, such as sketching, support or constrain the movement between the different levels of specificity. While sketching is often celebrated as a medium to foster design thinking, its value and approach in educational settings remain contentious (Härkki et al., 2018; Sung et al., 2019). As such, there's a need to question to what extent design related sketching skills are taught explicitly in schools and if these methods should mirror professional practices.

Within some design and technology education curricula, there often appears to be an emphasis on honing technical proficiencies, such as technical drawing often at the expense of foundational design skills like sketching and model making (Delahunty et al., 2012). This prioritisation might unintentionally overshadow the importance of nurturing innate designing abilities and the intuitive exploration enabled by sketching. The emphasis on technical skills over essential design skills creates a skewed understanding of the design process (Delahunty et al., 2012). Sketching and model making, for instance, are fundamental to the iterative design process, fostering creativity, flexibility, and the ability to rapidly visualize and refine ideas (Kimbell & Stables, 2008). By not giving these foundational skills the attention they deserve, we risk cultivating a generation of designers proficient in execution but potentially limited in innovative thinking. This imbalance is concerning, as it could stifle the emergence of novel design solutions. To better shape and guide the design journey, especially from an educational standpoint, it's imperative to understand the intricate layers of design thinking.

To support teachers in facilitating students' thinking processes, we highlight two hierarchical movements that are present during students' processes of iterative designing, including part-whole hierarchical thinking and implementation hierarchical thinking. We draw on Visser's (2006) systematic Decomposition Approach, shown in Figure 1, to highlight the non-linear, yet hierarchical movement between different levels of design thinking. We contend that evidence of the hierarchical thinking can be explored in the external representations that designers generate during their processes of designing, which we will explore in Section 3 of the paper.

Figure 1: Visser's (2006) systematic decomposition approach



Part-whole hierarchical thinking refers to the way in which designers can decompose a design idea into smaller parts and to think about the relationship between the parts that make up the whole design (Visser, 2006). In essence, part-whole hierarchical thinking entails a designers' ability to break a design down into constituent elements, sub-systems or components, which all contribute to the overall functioning of the whole design. Teaching students this thinking skill helps them to analyse and understand the design by examining the relationships and interactions between different components of the design. Furthermore, this skill helps designers to manage complexity by identifying components and understanding how changes in one part affect the whole design.

Implementation hierarchical thinking refers to the way in which designers represent their ideas in various levels of abstraction in terms of its implementation and realisation (Visser, 2006). These representations help the designers to consider the different levels of implementation, from the overall form to specific materials, technologies, aesthetics, and interfaces. Essentially, implementation hierarchical thinking helps designers to understand various design realisation factors, such as how design ideas can be developed from the conceptual phase into a tangible product, assessing the feasibility and cost implications of different implementation choices and to determine the manufacturing processes, materials, and technologies required for implementation.

Hierarchical thinking is essential for students to design effective solutions to real-world problems as it helps them to effectively analyse, organise and represent the complex relationships and dependencies resulting from their design ideas. This is especially important where the complexity of design problems and their solutions can be overwhelming. In this paper, we argue that students' ability to think in hierarchical ways, depends critically on the nature and types of design representations that students create during designing. These representations might include verbal, visual or gestural representations. For this paper, we focus solely on sketching and drawings as a vehicle for demonstrating and developing hierarchical thinking. Future research will include other representational media, including physical modelling and prototyping.

2.2. Design sketching as a cognitive activity

Sketching is a fundamental tool that has been traditionally used by designers to support design thinking and communication. While the process of thinking and decision making through the design process increasingly involves the use of modern digital technologies (such as CAD) and advanced physical prototyping methods (Karabiyik et al., 2023), the role of sketching as a tool to support design thinking remains highly valued. In the context of design education, design sketching is a journey that designers undertake where they create and use external representations / visual displays on a 2D surface (such as paper or a digital tablet) to support the exploration, manipulation, visualisation and evaluation of a product's spatial configurations (Goldschmidt, 1991; Yi-Luen Do, 2005). Such explorations support the development of their hierarchical thinking (Haupt, 2018; Visser, 2006) in exploring the various components in their design ideas, and also the various levels of abstractions needed to realise the design idea.

While many people view rendered and highly aesthetic perspective sketches that communicate a conceptual design (or product) as the gold standard of sketching, the journey in getting to that rendered final concept is often under-valued and sometimes even dismissed. Design sketching is an iterative and hierarchical process where arguments in the mind's eye oscillate and are externalised and developed on paper. It is imperative that these dialectics of sketching (Goldschmidt, 1991) are understood and embraced in D&T classrooms where sketching can become a powerful sense making tool to support idea generation, self-reflection, self-expression and reflexive thought (Jonson, 2002; van der Lugt, 2005).

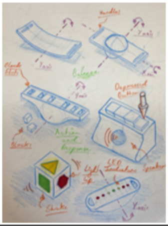
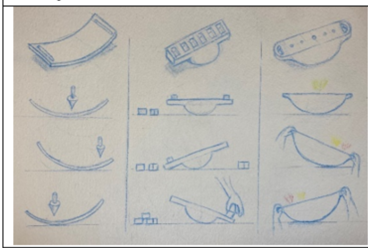
At a fundamental level, sketching can be considered as the externalisation of thinking processes during a design task, however, the value of the process goes beyond the marks created on paper by the user. Sketching presents the student with the opportunity to explore and reflect on complex, tacit and explicit internal processes (Dix & Gongora, 2011). The production of marks on paper not only records the design journey process but it also serves as a mental buffer enabling the student to retrieve, manipulate and synthesise information in an efficient fashion. This extends beyond the final sketches and helps the student to free up their mind to engage and think efficiently about the design task at hand.

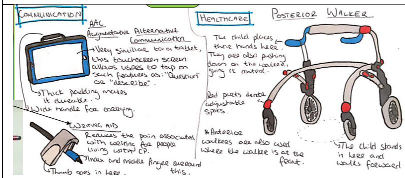
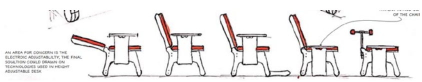
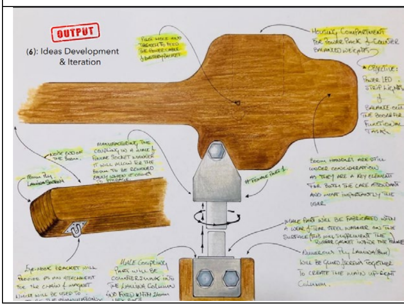
While it is widely accepted that sketching plays a key role in supporting design thinking, it is important that educators understand the cognitive role that external representations such as sketches play during designing. It is our belief that teachers could enhance their support for students during designing when they understand the cognitive role that sketches play in externalising and organising thoughts about design ideas, as well as, understanding the way in which sketches facilitate reflection, exploration, communication, and offloading information for the purposes of problem solving, ideation, comprehension and appraisal.

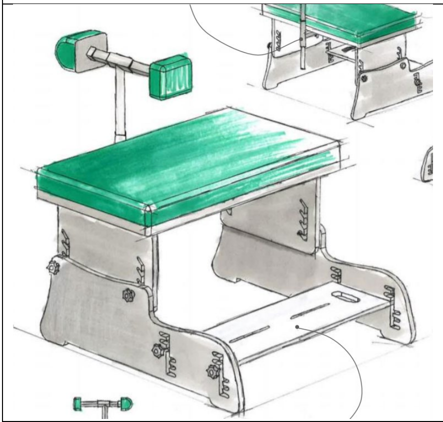
3. A TEACHING TOOL TO SUPPORT STUDENTS' HIERARCHICAL THINKING DURING DESIGNING

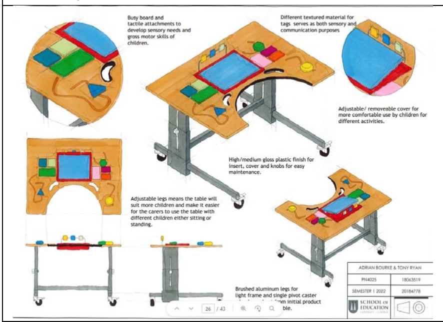
In developing a tool for design and technology educators to support the hierarchical thinking embedded in students' design sketches, we draw on the work of Pei & Self (2022), who developed a taxonomy of design representations in the context of professional design education. The work of Pei and Self (2022) provides a comprehensive and well-structured taxonomy that differentiates between different design representations and aided us in the analysis and interpretation of hierarchical elements in design representations. For this conference paper, we draw on eight different sketches that might be applicable to design and technology education and illustrate how they reflect various levels of hierarchical thinking. In the following teaching tool, we demonstrate that the properties in the different types of sketches could provide more information about the hierarchical thinking of students.

Figure 2: Teaching tool to support hierarchical thinking during sketching activities.

Sketch types	Properties	Part-whole hierarchy	Implementation hierarchy	Iterative design phase
Idea sketches				
	- Quick externalisation of ideas - Simple line work - Focus on design idea	Focuses on Global idea Level 1 (Global +)	Abstract ideas, with little references to implementation intentions (Concrete --)	During the initial phases of an idea
Study sketches				
	- Exploratory sketches to investigate appearance, proportion, scale, layout, configuration, or mechanism. - Loose use of tone and colour	Focusses on Global idea Levels 1 and 2 (Global)	Abstract ideas, with little references to implementation intentions (Concrete --)	During the initial phases of an idea

Referential sketches				
	- Used to record observations of stimuli for future reference, inspiration or as a metaphor - Emphasis on visual character	Focusses on Global idea Levels 1 and 2 (Global)	Abstract ideas, with little references to implementation intentions (Concrete --)	During the initial phases of an idea
Memory sketches				
	- Expanding thoughts about the initial idea. - Elaboration in the form of mind-maps, annotations, notes. - Tends to be information related to the scenario of use	Focusses on Global idea Levels 1 and 2 (Global)	Abstract ideas, with little references to implementation intentions (Concrete --)	During the initial phases of an idea
Coded sketches				
	- Informal categorisation of design information. - Tend to focus on operating and working principles of systems and components.	Focusses on detail idea Levels 2 and 3 (Detailed)	Developing ideas, with references to the physical and functional nature of the design ideas (Concrete -)	During the middle phases of an idea realisation
Information sketches				
	- Quick communication of design features. - Uses annotation and some colour. - Tends to focus on design intentions and construction information.	Focusses on detail idea Levels 2 and 3 (Detailed)	Developing ideas, with references to the physical and functional nature of the design ideas (Concrete -)	During the middle phases of an idea realisation

<table>
<tr><td colspan="5">Rendered sketches</td></tr>
<tr>
<td></td>
<td>- Focuses on representing a clearly defined idea proposal
- Use of colour and tone to enhance detail and realism
- Focuses on overall form and aesthetics</td>
<td>Focusses on detail idea Levels 2 and 3

(Detailed)</td>
<td>Developing ideas, with references to the physical nature of the design ideas (Concrete +)</td>
<td>During the middle phases of an idea realisation</td>
</tr>
<tr><td colspan="5">Prescriptive sketches</td></tr>
<tr>
<td>
</td>
<td>- Focuses on representing accurate technical details.
- Details include information about mechanisms, materials, manufacturing, dimensions
- Focuses on parts within a system</td>
<td>Focusses on detail idea Levels 3 and 4

(Detailed +)</td>
<td>Developing ideas, with references to the functional and implementation intentions of the design ideas (Concrete ++)</td>
<td>During the middle to end phases of an idea realisation</td>
</tr>
</table>

Rooted in the framework of Pei and Self (2022), Visser (2006) and Kimbell and Stables (2008), this teaching tool serves primarily design and technology teachers aiming to cultivate and enhance hierarchical thinking through design sketches within their students. The taxonomy of design representations by Pei and Self (2022), adeptly suited for professional design education, also finds relevance in the context of school-level design education, making it a versatile tool.

Using the tool is envisioned as an iterative process. As students progress through design projects, teachers can refer to the tool during specific sketching activities. The eight distinct sketches, carefully selected from the broader taxonomy for their relevance to design and technology education, act as markers or checkpoints. Each sketch type reflects a unique level of hierarchical thinking, allowing teachers to pinpoint and understand the depth and direction of a student's design cognition at any given stage. Moreover, the properties embedded in these sketches can serve as indicators, elucidating the nuances of students' hierarchical thought processes.

Thus, the optimal timing for using this tool would be during sketching sessions, critiques, or reflection periods in the design curriculum. Teachers can employ it as a reference point, both for guiding students and for interpreting their work. Additionally, as students become more familiar with the taxonomy, they too can leverage the tool for self-assessment, gauging their progression and areas of improvement in hierarchical thinking.

4. DISCUSSION AND CONCLUSION

In the evolving landscape of design cognition studies, hierarchical thinking has been noted as a significant driver in the iterative design process, with its roots tracing back to Hierarchy Theory (Allen and Star, 2017; Medland, 2007). Existing pedagogical models such as Gero's (1998) Function Behaviour Structure (FBS) framework and Vermaas's (2009) Model of Conceptual layering have significantly contributed to our understanding of the role of hierarchical thinking. However, the gap between design cognition and the use of design representations signals an opportunity for improvement in pedagogical practices. More specifically, our research seeks to bridge this gap, leveraging the principle of hierarchical thinking, and the newly proposed teaching tool provides a tangible method of developing teachers' and students' meta cognitive awareness of the externalisation of their designerly thinking, particularly those associated with part-whole and implementation hierarchical thinking (Visser, 2006).

Hierarchical thinking, as proposed by Visser (2006), forms the backbone of this teaching tool. It serves as a bridge for educators and their students to connect their design intentions with the representational embodiment. By providing areas for focus, this tool can help educators to guide students through the iterative design process, utilizing different sketch types at each hierarchical level. The emphasis on external representation of thoughts through sketches aligns with insights from previous research, stressing the importance of external representations in fostering self-reflection and self-expression (van der Lugt, 2005; Johnson, 2002).

Practical implementation of the teaching tool in real-world classroom settings does pose some challenges. For example, it requires educators to be cognizant of each students' representational capability (Welch, 1998). Modelling the various levels of detail and implementation requires specific expertise that needs to be learned and taught throughout the design process. This expertise isn't just limited to technical proficiencies like technical drawing but should also encompass foundational skills such as sketching and model making (Delahunty et al., 2012). Neglecting the latter can lead to a generation of designers proficient in execution but lacking in innovative thinking. As such, this places extra-curricular time demands on teachers and learners. Furthermore, committing to fostering hierarchical thinking during designing requires educators to delve deep into the nuances of the design process, valuing each step and not just the outcome. It's not just about the end-destination, but the entire journey of designing, emphasizing the essence of sketching and iterative processes which foster creativity and flexibility (Kimbell & Stables, 2008). This nuanced approach contrasts starkly with traditional design portfolios where design representations are often predetermined for assessment purposes.

Notwithstanding its promising implications, our research and the proposed teaching tool present some limitations. The taxonomy of sketches, their corresponding hierarchical levels, and their influence on student design thinking need further validation in diverse educational contexts. Future studies aim to investigate the graphicacy related skills required to think in designerly ways. While hierarchical thinking provides a cognitive structure that guides the design journey, it is graphicacy—the ability to interpret and produce graphical representation—that brings this cognition to tangible fruition. It's crucial to investigate the symbiotic relationship between these two entities. How do various graphicacy skills correlate with different levels of hierarchical thinking? Does a more advanced graphicacy capability enhance one's ability to navigate the complex layers of design thought? By delving into this interplay, we can better understand the foundational competencies students require to effectively engage with the multifaceted hierarchical levels of design thinking. This insight can significantly shape pedagogical strategies, ensuring students are not only mentally equipped but also technically skilled to traverse the design landscape. Also, the tool's effectiveness in enhancing design outcomes warrants empirical testing through longitudinal studies. Yet, as suggested by Haupt (2018) and Visser (2006), we believe that our work provides a pivotal step towards a more holistic understanding of the design process, sparking further exploration and innovation in design education.

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Great expectations: a Finnish Perspective on International Students' Choice of University-level Craft Courses

Pia Brännkärr, Åbo Akademi University, pia.brannkarr@abo.fi
Mia Porko-Hudd, Åbo Akademi University, mia.porko-hudd@abo.fi

ABSTRACT

University students have different motives and expectations when it comes to going on exchange and taking university courses in another country. Similarly, different motives and requirements impact course choices. Some exchange students who come to Finland choose to participate in craft courses. Craft as a school subject can be a new and foreign experience for many of them. The aim of this study is to investigate international students' rationales for taking craft courses during their university studies in Finland. It also focuses on what kinds of expectations they have from a craft course and how they are met.

This was a qualitative study. Data was collected through questionnaires at the beginning (n=26) and end (n=15) of a craft course in which both international students and Finnish students had enrolled. Only international students' answers were reported. Students answered open-ended questions about why they chose the course and their expectations from the course. At the end of the course, they were asked how it met their expectations. Themes for motives and expectations were identified using reflexive thematic analysis. Motives for the students' choices related to their interests in the craft subject, their development, benefits in future work, new opportunities and practical studio work. Expectations related to, among other things, participants' learning and development, learning from and helping each other, and learning things that would be useful in future work. The findings suggest that the content of craft courses is important and relevant to learn among students with diverse cultural backgrounds, regardless of whether they have similar subjects in their home countries.

Keywords: craft education, exchange students, international mobility, motives, expectations.

1. INTRODUCTION

Research has shown that exchange students (ESs) at Finnish universities with teacher education choose to participate in craft courses (e.g. Brännkärr, 2021; Kiviniemi, 2021; Kokko & Dillon, 2011, 2016; Kröger, 2012, 2020). In Finland, craft is a mandatory school subject in grades 1–7 and optional in grades 8–9 (Porko-Hudd et al., 2018). The subject's focus is that pupils learn to master the whole craft process. The aim is that pupils gain knowledge and skills useful for everyday life and develop their creativity as well as their motoric and planning skills (Finnish National Agency of Education, 2014). The subject involves planning and working with various materials and techniques, such as sewing, knitting, wood and metal work, and electronics, as well as 3D printing and programming. There are two categories of teachers in Finland: class teachers (generalists in all subjects in grades 1–6) and subject teachers (specialists in subjects in grades 7–9). Class teacher students in Finland are required to study craft, and craft science is a major subject at the four universities in Finland that educate subject teachers in craft. Craft as a school subject can be novel or even unknown among ESs (Kokko & Dillon, 2011, 2016).

ESs have certain requirements to complete their studies. For example, the Swedish-language university Åbo Akademi (ÅAU) in Finland, this study's context, recommends 30 credits (ECTS) per semester and 60 ECTS per full study year (Åbo Akademi, n.d.), and non-Swedish-speaking ESs are offered a limited number of courses (Study guide, n.d.). One such course is *Craft in Natural Materials* (CNM), which is worth five ECTS. This study focused on international students participating in this course, which is part of the basic studies in craft science and required for first-year students majoring in craft science. The course is also available to students taking craft as a minor subject and offered as an elective course for students in different study programmes, including international degree programmes, and ESs. The course includes extensive craft activities during which students use various techniques and materials. It is science-based and includes article reading, reflection, discussion and written assignments. Although the course language is Swedish, international students receive guidance and complete tasks in English. In this study, the term *international students* refers to both *exchange students* (ESs) who study in another country for a short period and *international degree students* (IDSs) who study in another country to obtain a degree.

This raises the following question: Why do students, coming on exchange to teacher education, choose craft courses during their stay in Finland? The aim of this study was to investigate the rationales that impact international students' decisions to take craft courses during their studies at ÅAU and their expectations from the course. The study was guided by the following research questions:

1. Why do international students choose craft courses?
2. What expectations do international students have from a craft course?

2. LITERATURE REVIEW

Researchers have identified several factors that motivate students to go abroad for exchange studies. According to Sova (2017), three drivers motivate students to go on exchange and choose specific courses during the exchange: discovery, change and curiosity. Discovery pertains to discovering something new or unusual and learning about a new country or culture. Change pertains to a change in one's environment by exploring a different country or culture. Curiosity pertains to exploring the unknown and the different; it is about students' interests and desire to learn, to be challenged and not to have expectations or a clear idea of what to learn.

Krzaklewska (2008) identified four areas of motivation for Erasmus students to go abroad: academic, linguistic, cultural and personal. The academic area pertains to learning about academic culture and different educational systems as well as gaining 'some kind of distinction which they [students] hope will make them more employable' (Krzaklewska, 2008, p. 90). The cultural area pertains to living in a new country and learning about a new culture. This is often connected to students' development of language skills, which is part of the linguistic area. The personal area pertains to new experiences, such as meeting new people, living in a foreign country and seeing different things. According to Krzaklewska and Krupnik (2006, p. 14), the top motivations for students to go on exchange are 'to practice a foreign language', 'to have new experiences', 'to enhance future career prospects' and 'to learn about different cultures'. A quantitative study conducted by Lesjak et al. (2015, pp. 853–854) found that the highest rated motivational factors among Erasmus students were 'to experience something new', 'to grow personally', 'to learn about different cultures', 'to meet new people' and 'to have a semester away from home'. Professional and personal growth are the main reasons students join Erasmus programmes (Lesjak et al., 2015). Erasmus+ is a European Union programme that offers, among other things, mobility and cooperation opportunities in higher education (European Commission, n.d.).

Krzaklewska (2008) constructed a theoretical model of motivation for going abroad to study. The model consists of two dimensions with two categories each. The experimental dimension, which contains the categories of cultural motivation and personal motivation, pertains to having new experiences, learning about cultures, self-development and having fun. The career dimension, which contains the categories of career motivation and academic motivation, includes, for example, improving academic knowledge and future employment opportunities. Although linguistic motivation is important, it lacks a clear place in the model, as it can fall under cultural, personal or career motivation. According to Krzaklewska (2008), all the types of motivation are interrelated, and motivation for going abroad can be described as, among other things, expectations.

Students' expectations from exchange studies can concern the studies, getting to know the host country, social relations, and personal growth and development (Hietaluoma, 2001). Students expect to improve their self-confidence as well as their social and communication skills (Costas & Singco, 2016; Hietaluoma, 2001). Their expectations can also focus more on having fun and adventure than on academic growth and developing competencies (Stronkhorst, 2005). Nilsson (2015) stressed that students' expectations are more about personal than academic expectations. Students want the exchange to be an adventure, they enjoy the change in their study environment and learning about other cultures (Nilsson, 2013, 2015). ESs are also motivated to learn the local language outside language courses and therefore try to find opportunities to use it (Kalocsai, 2009). Students have positive expectations, and their attitudes are even more positive after the exchange (Nilsson, 2013). They also expect exchange studies to be a challenge.

3. DATA AND METHOD

This was a qualitative study. Data was collected through questionnaires completed by international students at the beginning (n=26) and end (n=15) of the CNM course. The questionnaire at the beginning of the course was used for three years, while the questionnaire at the end of the course was used for two years (Table 1). Between each year, we made minor adjustments to the questions in the questionnaires to improve them. In 2019 and 2021, ESs and Finnish students participated in the course, while in 2022, IDSs also participated in the course. All students attending the course had the opportunity to fill out the first questionnaire at the start of the course. Questionnaires were chosen over interviews to minimise the risk of influencing participants' answers. The course had two teachers. Due to one of the teacher's dual roles as a teacher and researcher, it was carefully pointed out to the students that participation in the research was optional and unrelated to the course assignments and that it would not affect course grading. The second questionnaire was sent out after grading was completed to avoid ethical dilemmas due to participants being afraid of their answers affecting their grades. We could possibly recognise students based on their answers due to the small size of the groups. The first questionnaire focused on students' motives for enrolling in and their expectations from the course, such as learning outcomes, working methods, materials, techniques, tasks and interaction with others. The questions were open-ended. The second questionnaire focused on how the expectations were met during the course. It included a mix of open-ended questions, multiple choice questions and statements with a four-point Likert scale. This article reports the answers obtained from the open-ended questions and only answers from international students were used.

Table 1.
Overview of empirical data

Year	Course participants		Answers to questionnaire, international (Int)	
	Total	International (Int)	Beginning (first)	End (second)
2019	28	10	9	-
2021	25	13	6	7
2022	31	15	11	8
Total	84	38	26	15

Reflexive thematic analysis was used to analyse the answers because it allowed us to identify themes across the dataset and to use both an inductive and deductive approach. Reflexive thematic analysis consists of familiarising oneself with the data material, making initial codes, organising the codes and generating and defining themes by combining codes (Braun & Clarke, 2006, 2022). NVivo was used to conduct the analysis. During the first readings of the data, initial codes were made inductively, with separate codes for motives and expectations. The initial codes were evolved and some clustered together. During the development of the initial themes, we recognised similarities with the results of previous studies. The final themes for both motives and expectations were therefore developed based on Krzaklewska's (2008) theoretical model of motivation for going abroad. The codes for motives were collated into the following themes: *cultural motivation, personal motivation, career motivation* and *academic motivation*. Students' expectations from the course can be seen as related to their motives for choosing the course; therefore, the same theoretical model was adapted to expectations. The codes for expectations were collated into the following themes: *cultural expectations, personal expectations, career expectations* and *academic expectations*. The same answer could be coded into more than one theme depending on its characteristics and content. After the themes were developed, the coding was refined and reviewed to ensure validity.

4. RESULTS

4.1. Motives for course choice

Personal motivation for course participation consisted of students' interest in the craft subject, own learning and knowing, and the novelty of the craft (course). It was clear that the students saw the course as fun, interesting, challenging and an opportunity to enhance their well-being. The few answers within *cultural motivation* related to experiencing Finnish craft, nature education and something different from their home country, these could also relate to academic motivation. *Career motivation* was related to students wanting to learn craft and other things for the future, and for the future work as a teacher or working with children. For example, while some students wrote more openly about implementing knowledge and skills at home, others specified work and activities at school:

> I'm hoping that this course will teach me some of the basics on the topic and give me some ideas on how to include craft into my own private life as well as into teaching methods at primary school. (Int.19-4)

Academic motivation concerns recommendations about the course from students or teachers at the home university, the course being validated at the home university and students' choice of specialisation at their home university. Specific aspects of the craft course – such as its content and diversity, that it concerns practical studio work, its distinctness from courses at the home university and that students see craft as an important subject – are also related to academic motivation. Several students mentioned the nature or natural part, found in the course name or information, as motivational. One student saw the course as an opportunity to learn about basic education in Finland. The following quote illustrates how various aspects of academic motivation motivated the students to choose the course. It also illustrates an example of students' own interest in the subject as part of personal motivation and an example of career motivation when thinking about the future.

> In my home university we can choose a focus and I took creativity. […] I love to work with different materials and techniques. This course was also recommended by my teachers [...] I would like to get to know a lot of practical units, which I can also use or implement at home. (Int.22-1)

Students' motivations for taking a craft course mostly centred on academic motivation and personal motivation, especially their learning and interest in the subject. The least emphasis was on cultural motivation.

4.2. Expectations from the course

Course expectations have similarities with the motives. *Cultural expectations* include getting an overall picture of Finnish education and craft and students' development of attitudes to nature; they are not specifically about the course or studies at ÅAU. Students expect to learn about other cultures. The following quote is an example of this kind of cultural expectation:

> Since there were students from many different backgrounds, I hope to share many thoughts and experiences together. And I also would like to support other students. (Int.22-6)

However, as with motives, students' expectations emphasised this theme the least.

Personal expectations include students' expectations about their development, learning and skills. They expect not only to have fun and to find the course interesting but also to be challenged. Trying, experiencing and learning new things is something many of the students highlighted as expectations. Expectations about interactions and contact with other students were found within this theme. Expectations are, as seen in the quote above, about supporting, helping and learning from each other. It is also about seeing what others do, learning to cooperate and getting to know each other.

Career expectations include students' expectations of doing and learning useful things for their future lives and careers, such as craft experiences and ideas to use with children. What these things are can also be undefined: 'I will have fun while learning something really useful for my future job' (Int.21-3). The context of the answer indicates that the mentioned usefulness has to do with content and pedagogical methods in crafts. Expectations also relate to gaining knowledge about how to teach craft and getting didactical thoughts or insights.

Academic expectations are mainly about the specific craft course students attend and pertains to the course design and content. Students expect the course to be practical and provide them with opportunities for creativity and making tangible artefacts. Some expressed expectations to obtain theoretical knowledge. Many aspects of this theme were stated in the course description and in the information provided by the teachers in the first class. Students stated that they expected to learn many techniques and use many different materials without specifying what 'many' is. When the students specified materials and techniques, they mostly listed the materials from the course information. It is worth noting that many mentioned 'natural materials' without specifying exactly what they are. This indicates that the course name, Craft in Natural Materials, impacted expectations. A few codes did not belong to any specific theme, such as learning Swedish words, which only one student expressed as an expectation. As mentioned in previous research, this could be placed within several themes. Some expectations were vaguely expressed and therefore not placed in any of the themes. These were related to students' openness and their expression of having high expectations.

The results imply that students' expectations from the course can be interpreted as great or 'excellent', as one student wrote. Overall, regarding how their expectations were met, the students were very satisfied. Only one student out of 15 listed expectations that were not fulfilled. They pertained to working more in nature and having clearer instructions. Working more in nature can again be an indication of the impact of the course name. All the other students said that their expectations were fulfilled or even exceeded.

5. DISCUSSION AND CONCLUSION

While both academic and career motivations and expectations were clearly discernible in this study's results, previous studies have shown more emphasis on the personal aspect (Nilsson, 2015; Stronkhorst, 2005). The academic context of this study may have significantly influenced the answers, resulting in the observed focus on academic and career motivations and expectations. This study's results about learning for the future may reflect how future career prospects can be among students' top motivations for going on exchange (Krzaklewska & Krupnik, 2006). As in other studies, the personal motivations and expectations were clearly discernible. Students being motivated by the fact that the course is a new kind of opportunity for them reflects what previous research has revealed about students' desire to experience something new during an exchange (Lesjak et al., 2015; Sova, 2017). As seen in previous research (e.g. Krzaklewska, 2008; Sova, 2017), students want to learn about other cultures during their exchange, and some participants saw the opportunity and expected to achieve this through the course by being in contact with students from diverse backgrounds. The findings regarding participants' expectations to learn to cooperate were in line with those of Costas and Singco (2016) and Hietaluoma (2001), especially in terms of social and communication skills. This study's results were also similar to those of Hietaluoma (2001), Nilsson (2013) and Stronkhorst (2005) in that they found that students expected to have fun and expected the course to be interesting and challenging.

This study's findings differed from those of previous studies in that only one participant wrote about learning a language (see Kalocsai, 2009; Krzaklewska & Krupnik, 2006). This finding is remarkable given the context, as international students were mixed with local students, and the course language was Swedish. The presence of vague answers that could not be coded into themes indicates that perhaps the students did not really know what to expect from the course. This is in line with Sova's (2017) study, which found that students did not have clear expectations about what they wanted to learn. In the second questionnaire, some participants stated exactly this – that they did not know what to expect at the beginning of the course.

In conclusion, craft as a university-level subject seems to be appealing for international students. The unknown can make craft appealing, as well as the opportunity to engage in practical studio work. Many of the participants expressed an interest in crafts and working with their hands. Craft and its content can be considered relevant for students, both personally and in relation to their future work. A course or subject being novel might impact students' ability to define their motivations and expectations. The course name and description may therefore play a vital role in this regard.

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Gifted Students' Needs in Technology Education

Helen Brink, Karlstad University, helen.brink@kau.se

ABSTRACT

Students who are gifted and students with high abilities can have special educational needs. Teaching should be challenging and stimulating and teachers and educators in inclusive settings have a variety of needs to consider, included the gifted students' needs. However, when it comes to technology education, little is known about gifted students' needs. The aim of this ongoing study is to describe and synthesize knowledge about gifted students' needs in technology education through a systematic research literature review and a thematic analysis. The tentative results are four themes describing gifted students' needs in technology education as *Complexity, Autonomy, Support*, and *Authenticity*. The themes can be used by teachers and guide them in their efforts to plan and implement diverse and differentiated technology teaching as a proactive response to the gifted students' needs in inclusive settings.

Keywords: gifted education, needs, literature review, differentiation, inclusion

1. INTRODUCTION

Students that learn with ease, reach learning goals with ease, and those who are ahead of their peers in their knowledge development, are differently described in different contexts by researchers. For example, these students can be referred to as gifted, talented, high achieving, students with high ability or high potential (Dai & Chen, 2013; Mellroth, 2018). These concepts, all describing the students, are complex and culturally specific in terms of where and to what extent different personal abilities and characteristics are valued, hence the variety (Al-Hroub & El Khoury, 2018; Kaufman & Sternberg, 2008; Sak, 2021). In this paper, *gifted students* will be used when describing students that learn with ease, and this term should be understood as an overlapping umbrella concept including talent, high achieving, high ability, and high potential. Giftedness should also be seen as a developable ability (Gagné, 2004; 2005). In a school context, teachers need to recognize multiple forms of giftedness and there is a call for educating teachers about the needs of gifted students (Campbell et al, 2022; Laine & Tirri, 2016; Rimm et al., 2010). If those needs are not met, there is a risk that gifted students will not reach their potential, will underachieve, or may even drop out of school (Rimm et al., 2010). There is a lack of research studying gifted students' needs from different perspectives and in relation to different subjects, and also a lack of research studying how these needs can be met in specific educational contexts, for instance technology education. Themes, describing gifted students' needs from the technology education perspective, can help develop both gifted education and technology education and guide teachers when designing differentiated technology education for inclusive settings.

2. AIM AND RESEARCH QUESTION

The aim of this systematic research literature review is to develop themes for technology education by identifying and synthesizing knowledge about technology education for gifted students. The research question is:

- What needs of gifted students in relation to technology education are pointed out in research literature?

3. EDUCATION FOR GIFTED STUDENTS

There are general approaches to teaching gifted students, but no clear recommendations are given for the subject technology. These approaches can be applicable in all school subjects. *Differentiation* is one approach to teach gifted students, and other approaches are *enrichment* and *acceleration*.

Differentiation is a pedagogical and proactive response to the needs of different students in the classroom (Tomlinson, 2016). Many school systems have an inclusive approach, meaning that students with a diversity of needs are taught jointly. Differentiation involves variations in teaching, and these variations can relate to instruction, content, methods, or assessments. The variations can be supportive, or they can be challenging. Differentiated teaching can address students' prior knowledge, interests, and motivation through four different variants: differentiating the content (where, for example, the learning material can start at an abstract and complex level and stimulate higher order thinking), differentiating the process (working in different ways with a material), differentiating the outcome (as a result of varying content or methods), and differentiating the learning environment (based on students' different needs, e.g. group work with people similar to oneself) (Mellroth, 2021; Tomlinson, 2016).

Enrichment is described by Gagné (2007) in terms of difficulty, depth, diversity and density. He describes that gifted students can work with material that is more complex and advanced (difficulty); with more detailed material (depth); with content that is not described in the curriculum (diversity); or with compressed course content to avoid repetition of what he or she already knows and masters (density). Subject-specific enrichment is the most effective in stimulating gifted students, as opposed to more general enrichment without clear objectives (Freeman, 2004).

Acceleration can be used to differentiate instruction. Since some students are quick learners, they may be allowed to progress more quickly through a subject and access more advanced content (Little, 2018), perhaps finishing courses earlier than planned. Another way to accelerate is to attend one or more grades higher than the age indicates (Sims, 2021). There are recommendations to slow down the pace for gifted students. So, while gifted students need complex and advanced content, they may also need support to deeply absorb the content and engage with the task (Little, 2018).

4. TECHNOLOGY EDUCATION

Technology education differs in aim and content between different educational systems and countries. In the UK for example, the subject *Design and Technology* emphasizes design and design processes (Department for Education, 2022). Design includes functionality, fitness for purpose, form and aesthetics. Food technology with a focus on raw material processing is also a part (Barlex, 2018; Rutland, 2018). In Finland, the technology subject includes crafts with a focus on design processes, craftsmanship with different types of materials, and problem solving (FNAE, 2022). In Sweden, technology education should provide students with abilities to reflect on and develop knowledge of technological solutions, and to solve technical problems with technological methods (SNAE, 2022). In both New Zealand and the US, technology education focuses on technological literacy (Milne, 2018; Reed, 2018). According to Rossouw et al. (2010), technological literacy can refer to what people need to know to live with and control the technological environment that surrounds us. It includes practical knowledge, the ability to reason about technology, and also attitudes towards technology. It is argued by Nordlöf et al. (2022) that even though technology education varies between different countries, it generally involves three categories in terms of content, namely technical skills, technological scientific knowledge, and socio-ethical technical understandings.

Education involving technology can be integrated with other subjects, such as science and mathematics. STEM (Science, Technology, Engineering, Mathematics) education has a focus on authentic learning and real-world problem solving (Hallström & Schönborn, 2019; Ülger & Çepni, 2020). In STEM education, teachers often apply an integrated approach to teaching and learning and the specific subjects are not separate but instead treated as one fluid unit (Ülger & Çepni, 2020). Regardless of the curriculum used, and wherever in the world technology education takes place, teachers may encounter gifted students in their teaching.

5. METHOD

A systematic research literature review (Hart, 2018) was conducted and complemented with a thematic analysis (Braun & Clark, 2006). Two databases with relevance for educational science were chosen: Educational Resources Information Center (ERIC) and SCOPUS. The search was limited to peer-reviewed articles in English published from 2010 in academic journals. Around 2010, many countries adopted new curricula (c. f. Department for education, 2022; FNAE, 2022; SNAE, 2022) and therefore searches were limited to 2010 and beyond. Five different searches were conducted (Table 1).

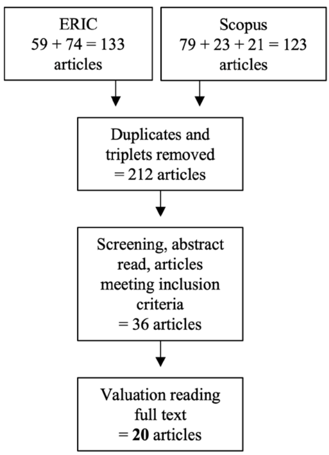
The five searches resulted in 256 articles (Figure 1), and after removing doublets and triplets, 212 articles remained. Three inclusion criteria were developed for the screening (title, abstract, and keywords), all of which had to be met: relevance for a) technology education or STEM education, b) gifted education, c) gifted students' needs.

Table 6.
Description and summary of articles

Date of search Database	**Search blocks**	**Total**
230118 ERIC	ALL (Gifted* OR Talent* OR ”high achievers” OR “high* able” OR “high ability” OR “high potential”) AND (“technology education” OR “STEM education” OR engineering) AND needs	59
230118 Scopus	ALL (Gifted* OR Talent* OR ”high achievers” OR “high* able” OR “high ability” OR “high potential”) AND (“technology education” OR “STEM education”) AND “student needs”	79
230127 Scopus	TITLE-ABSTRACT-KEY (Gifted* OR Talent* OR ”high achievers” OR “high* able” OR “high ability” OR “high potential”) AND (“technology education” OR “STEM education” OR engineering) AND “student* need*”	23
230127 Scopus	TITLE-ABSTRACT-KEY (Gifted* OR Talent* OR ”high achievers” OR “high* able” OR “high ability” OR “high potential”) AND (“technology education” OR “STEM education” OR (engineering AND K-12)) AND needs	21
230204 ERIC	TITLE-ABSTRACT-KEY (Gifted* OR Talent* OR ”high achievers” OR “high* able” OR “high ability” OR “high potential”) AND (“technology education” OR “STEM education” OR (engineering AND K-12)) AND needs	74

This screening resulted in 36 articles chosen for a full text reading, where 16 articles were excluded since the topics of those articles (for instance policy, leadership) were not within the scope of this study.

Figure 3.
Search process



After this systematic search, the final 20 articles were coded and analyzed thematically (Braun & Clark, 2006). First, notes were added to data extracts associated with gifted students' needs in technology education. The notes then were organized into meaningful groups and coded, and 21 different codes emerged. The data were coded inductively to prevent preconceived impacting. The codes were collated into themes based on similarities and aspects of meaning related to each other. The themes of gifted students' needs in technology education were finally named (Table 2).

Table 2.
Codes and Themes

Codes	Theme
Abstraction, Complex activities and thinking, Experiments, Conceptual explorations	Complexity
Pace, Perfection, Independence, Responsibility	Autonomy
Feedback, Mentors, Ethics, Discussions, Acknowledgement, Freedom	Support
Open-ended tasks, Creativity, Holistic, Interdisciplinary, Metacognition and transfer, Real-life problems and situations, Meaningfulness	Authenticity

6. FINDINGS

Four themes of gifted students' needs in technology education emerged: *Complexity*, *Autonomy*, *Support*, and *Authenticity*. A brief description of the themes will be presented next with some examples from the final selected articles.

6.1. Complexity

Complexity advocates that gifted students in technology education need advanced work and complex activities that allow them to explore concepts on an abstract level and conduct advanced experiments with a focus on understanding (Torkar et al., 2018). Experiments can aid and support concept understanding while building models and structures for visualizing concepts. Complex content or complex systems of ideas with great depth and significance can meet high abilities and stimulate higher-order thinking, that is, analyses, syntheses, and evaluations (Taber & Cole, 2010). Higher order thinking can help develop content and concept understanding. Gifted students also need to be continuously challenged, and complex activities, advanced experiments, and conceptual explorations allow new connections to be made between the concepts in a challenging way.

6.2. Autonomy

Autonomy refers to the gifted students' needs for self-regulated learning and a sense of freedom. Gifted students often take a role as active learners and assume responsibility of learning processes and of the outcomes of current projects. They need to feel that they are in control of the depth and breadth of the content and learning processes (Morris et al., 2021). Further, they need some freedom in choosing activities that can be motivating for them, and they need to be able to adjust the pace of the learning. In other words, they need to feel that they have ownership over the activity and that they are in control of the situation, content, and pace. New and additional content introduced at a fast pace allows for making connections between concepts and thinking in an abstract manner. In addition, gifted students need to perform activities to the level of perfection that they themselves find sufficient, which affects the pace and duration of the activities. A part of autonomy is also the possibility for gifted students to express themselves in any way they choose. When given these opportunities, gifted students can work intensely to learn and to create a final product.

6.3. Support

Support describes gifted students' needs for response, feedback, discussions, and acknowledgement in relation to technology education (Tosunogly & Yildiz Durak, 2022). Even though gifted students need autonomy, they also need guidance in their choices. The guidance helps them focus and achieve what is currently beyond their reach. The response and feedback should be continuous and also adjusted and adapted to each individual student (Monteiro et al., 2012). Further, gifted students need in-depth discussions. These can be held with for instance their teachers, their peers, or mentors from outside the school. The discussions can be on different types of content and different processes or about ethical issues (Abdurrahman et al., 2019). Various competing interests can be discussed and different perspectives can be highlighted and respected. Such discussions challenge gifted students cognitively and help develop higher order thinking.

Acknowledgement is an important part of *Support*, and gifted students need to be acknowledged for their competence as well as for their abilities and potentials. This is discussed by Monteiro et al. (2012), claiming that it is not enough for the gifted students to recognize their own potential and personal abilities, they also need others to recognize them, especially their teachers.

6.4. Authenticity

Authenticity indicates that gifted students need meaningful and relevant activities based on real-life problems and situations (Morris et al., 2021). They need to get a grasp on the bigger picture, see the whole context, understand the historical perspectives of a situation, and work with learning content using an interdisciplinary approach.

When working with real-life problems, gifted students need to work with authentic methods used by professionals, and they need hands-on tools and materials to carry out physical solutions (Abdurrahman et al., 2019). The authentic activities can advantageously be open-ended, and findings and solutions can be reported to a real and interested audience (Taber & Cole, 2010; Torkar et al., 2018). The open-ended activities create opportunities for gifted students to be creative, to find creative solutions to problems, and to present them with questions that promote creative thinking. This interdisciplinary approach and open-ended activities open up for gifted students to think of their learning and develop their metacognition (Taber & Cole, 2010). Taber

& Cole (2010) argue that this is important for gifted students in technology education. Open-ended activities can in addition also satisfy gifted students' need for knowledge transfer, that is, to use knowledge from one context and apply it in novel situations (Abdurrahman et al., 2019).

7. DISCUSSION

As a complement to general approaches for teaching gifted students (differentiation, enrichment, acceleration) the resulting themes from this literature review describe needs of gifted students in technology education. Gifted students are a heterogenous group (Dai & Chen, 2013) thus they may have varying degrees of needs from the themes. However, the themes can function as a guide for teachers to ensure that gifted students' needs are taken into consideration.

The theme, *Complexity,* aligns with differentiated teaching (Tomlinson, 2016) as technological concepts and methods can be taught in various ways. For stimulating gifted students, the focus should be on understanding concepts, which is supported by Freeman (2004) suggesting subject-specific enrichment as the most effective form of stimulation. Technological concepts and methods are subject-specific even though they can be intertwined with other disciplines. Interdisciplinary content is yet another way of meeting the needs for complexity. When they encounter different perspectives and approaches in one area, gifted students can discuss dilemmas and different options that also relate to other areas, meanwhile developing higher order thinking.

Gifted students should be given opportunities to be autonomous, independent, and able to make some of their own decisions in technology education. The theme, *Autonomy*, describes this and can be understood as self-regulated or student-centered learning (Morris et al, 2021). When gifted students are autonomous, they can be creative and choose methods based on professional preferences when solving problems. Gifted student typically wants to use methods applied in real-life settings. Therefore, the freedom of choosing a method and a suitable level of creativity is important. If access to material and tools is provided, technological problems can be understood as real and meaningful (Morris et al., 2021). However, gifted students should be given a great deal of freedom under supervision, as they also need *Support* to focus and not get caught up in perfectionism when creating solutions. The pace of learning, which should be fast, is important for gifted students (Little, 2018). Thus, it is important that gifted students are given enough time to solve problems in their own ways.

When gifted students are presented with real-life technological problems, they are given opportunities to work with different perspectives. This can give the students a holistic understanding of technology, and according to the literature this is important (Morris et al., 2021; Torkar et al., 2018). Authentic problems and open-ended activities can have a positive impact on gifted students' motivation (Taber & Cole, 2010), as has the degree of choice in activities. *Authenticity* in technology education can cater to gifted students' needs for self-regulated learning since students take an active role as investigators (Taber & Cole, 2010) when solving the problems. When students use a self-regulated approach in technological activities, they can nurture their metacognition while reflecting on and reasoning about their own abilities (Torkar et al., 2018). Further, when students are working with transfer, new situations and interdisciplinary contents, they also nurture their metacognition.

Mentoring is discussed in the research literature about gifted education. In technology education, gifted students need to discuss content and methodological issues in terms of in-depth and up to date knowledge with competent people (Abdurrahman et al., 2019; Monteiro et al., 2012) in order to construct, deepen, and widen their learning. Preferably a mentor can represent the professional community of engineers, and he or she can act as an expert in a technological field discussing concepts, understandings, and dilemmas with the gifted students. A mentor can also act as a role model for gifted students, someone who they can identify with. In this way, since the mentor has real-life experience in the area of study, authenticity is provided.

This review makes an important contribution with knowledge about gifted students' needs in technology education, and provides teachers and teacher students with themes that can be used when designing differentiated teaching activities. Teachers can take into account the four themes and use them to provide for gifted students to have their needs met. The themes can also be used when comparing different technology educational traditions and can facilitate a common understanding of gifted students' needs.

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Considering the Credibility of Technology Education Research: a Discussion on Empirical Insights and Possible Next Steps

Jeffrey Buckley, Technological University of the Shannon, jeffrey.buckley@tus.ie

ABSTRACT

Technology education is a maturing research field. If studies are conducted which lead to suggestions for practice – which many are – as such changes can impact a substantial number of learners and require significant resources it is essential that the underpinning results are credible. Therefore, much like there are standards for educational practice, standards in research are equally as important. Such standards help ensure that findings are valid and trustworthy.

There are several dimensions to research credibility, such as replicability, reproducibility, the clear presentation of research questions and/or hypotheses, and reporting transparency, and it is important that the credibility of technology education research is considered for several reasons. In addition to ensuring sufficient empirical support for recommendations for practice, credibility is important to ensure trust in findings from both researchers and the wider community of stakeholders. It is also important for new studies which build upon prior work, that the evidential strength of the prior work is clearly understood.

Over the past two years, several studies have been conducted to examine current levels of credibility dimensions, specifically replicability and transparency, in technology education research. In this paper, the results of these will be briefly summarised with a view towards suggesting general areas for improvement and in providing practical ways in which to do so. More importantly, through this paper a broader discussion can be started around what standards should be considered for technology education research across different dimensions of credibility. Finally, other ways in which research credibility can be examined will be considered with a view towards gaining an understanding of what the technology education research community consider as more or less important within this research agenda.

Keywords: Research credibility, Trustworthiness, Research standards, Replicability, Transparency.

1. INTRODUCTION

As a research field technology education is relatively young, at least in comparison to its science, technology, engineering, and mathematics (STEM) counterparts. There are several indicators of the emergence of a field of study, such as the establishment of higher education programmes, academic conferences, and academic journals. Taking the first publication[5] of a field specific academic journal with a research dissemination aim as a proxy indicator due to the accessibility of information, the *Journal of Technology Education* was first published in 1989 and represents the first journal with a function dedicated solely to technology education. This was closely followed by the first issue of the *International Journal of Technology and Design Education* in 1990, which together would indicate that technology education as a research field is now just over 30 years old. That said, the earliest related academic journal with a field related remit was *Research in Science and Technological Education* in 1983, meaning technology education research is now 40 years old by this measure. This journal however notably includes a dedicated aim of publishing science education research as well, and while there are technology education research articles published within its initial issues, they are sporadic amongst the largely natural science education literature base. In comparison, the journal *Science Education* published its first issue in 1916, the *Journal of Engineering Education* was first published in 1924, and the journal *Educational Studies in Mathematics* was first published in 1968.

When looking back at the nature of technology education research over the past three to four decades, loose trends are visible. In its first two decades (the 1980's and 1990's), several articles which describe practice internationally were published. For example, Williams (1993) described technology education in Australia, Ankiewicz (1995) in South Africa, Owen and Heywood (1990) in Ireland, and Zuga (1997) in the United States. These descriptions were not just limited to national practice holistically, but also included descriptions of facets of practice. For example, Payne et al. (1993) described the use of portfolios for assessment and Kimbell (1994) spoke about types of tasks in technology. The next decade (the 2000's) saw a shift from a descriptive focus to what could be considered a framing agenda. Several articles which presented argument or debate concerning "big ideas" in and for technology education were published. For example, Turnbull (2002) presented an argument for the place of authenticity within technology education, Zuga (2004) and de Miranda (2004) frame the need to give consideration to cognition within technology education research and practice, de Vries (2005) reflects on the nature of technological knowledge, and Williams et al. (2008) framed problem-based learning as an appropriate pedagogy for the field. Following this, in the 2010's there appears to be another shift towards broad empirical generalisations to underpin advances in practice. Seitamaa-Hakkarainen et al. (2010), for example, present a study on learning by collaborative designing, there was a substantial initiation on the use of adaptive comparative judgement (ACJ) for assessment (Williams & Kimbell, 2012), Kallio and Metsärinne (2017) explored how learning orientations were related to learning outcomes, and Garikano et al. (2019) presented a study on a strategic knowledge-based approach for computer aided design (CAD) learning. Taking some of the most recent publications as an example, in the first few years of this decade (2020-2023) published empirical work appears to be focussed on more specific aspects of education than in the previous

[5] This commentary relates to English speaking journals only, as this the only language that the author is proficient in.

decade. For example, Ye et al. (2023) present an eye-tracking study on the processing of a dovetail joint, Larsson and Stolpe (2023) examine teachers use of gesturing when teaching programming lessons, and Liu et al. (2023) explore the use of a specific underwater robot construction kit. Of course, this is a very broad characterisation of the types of studies published over time and does not reflect all publications during this period, omits any form of review of the subject or topic areas of the studies themselves, and is limited to works published within the *International Journal of Technology and Design Education* due to the journals' size, but it does present a growth in the field from description in the early establishment years through to examination of specific theories and practices.

Parallel to a visible shift towards specificity has also seen a natural rise is the conduction and publication of meta-research, typically undertaken with a consolidation and future progress objective. One of the largest meta-research initiatives undertaken to date in technology education has been by Williams with colleagues where the aims and trends of related research have been characterised with changes over time being documented. Beyond this, there have been several reviews of the field (de Vries, 2003; Petrina, 1998; Reed & LaPorta, 2015; Sherman et al., 2010; Wells, 2015), however the two conducted by William's (2013, 2016) are broader in scope and/or remit, and were further built upon recently by a review of research trends from Xu et al. (2020). Collectively, these three reviews describe trends holistically in technology education research from 2000 to 2018. As the field has progressed, there has been an increase in review articles on more specific topics which often now include a degree of systematicity either in the search process, the review process, or both. For example, Gómez Puente et al. (2013) presented a review of design-based learning in technology education with a systematic characterisation of the included studies. Since this, however, it was not until 2021 that a review article has been published in an issue the *International Journal of Technology and Design Education* which has been explicitly described as systematic in some degree, and there have now been five such reviews (Bartholomew & Jones, 2021; Brosens et al., 2023; Chu et al., 2023; Eliasson et al., 2023; Jackson et al., 2022). This increase in systematic reviews is another indicator of the ongoing maturation of the field.

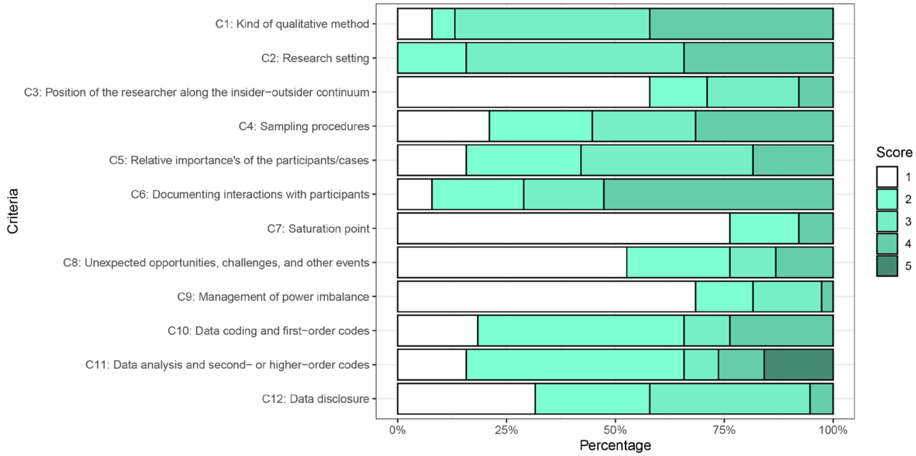
Meta-research goes beyond reviewing research trends and summarising topic related findings. It includes all works where the aim is to review, evaluate, or synthesise aspects of prior research. To take an example, research on the use of ACJ for assessment in technology education has grown in recent years. Bartholomew and Jones (2021) conducted a systematised review of associated findings with a view towards making suggestions for future research directions, however Buckley et al. (2022) reviewed the methodological validity of the included studies with an aim of informing the design of future studies. Both are meta-research projects on the same topic, with one aiming to inform future research questions and the other future research designs. This plurality is important as over the last decade several fields of study have been undergoing a "crisis of confidence" due to findings failing to replicate in replication studies (Anvari & Lakens, 2018). These fields, which include psychology, medicine, and experimental economics, are typically much older than technology education. As technology education has arguably entered or is entering quite a mature phase where research is becoming more explicit and systematic in terms of process, it is essential that meta-research with a focus on improving research practices becomes routine and translational. While a new agenda in technology education, in this paper two such projects are described and are followed by a discussion on possible next steps. These projects related to meta-studies on research transparency and result replicability.

2. TRANSPARENCY IN TECHNOLOGY EDUCATION RESEARCH

Making research transparent involves making all decisions made by researcher, particularly those relating to data, clear when reporting empirical studies (Closa, 2021). Typically, this involves researchers ensuring that methodology sections in their publications are comprehensive and unambiguous to the point where an exact replication attempt would be possible (assuming access to required resources) by an independent researcher. High levels of transparency are needed both to permit replication attempts, but also to ensure reported findings can be fully understood so they can be evaluated perhaps for contextual relevance or utility. There are several aspects of studies which need to be made clear for this to be possible, such as the type of methodology, sampling procedure, and analytic strategy. Aguinis and Solarino (2019) performed a systematic review across several fields to develop their behaviourally-anchored rating scales (BARS) instrument. Designed for qualitative studies, the BARS instrument included 12 criteria against which aspects of reported research methodologies can be scored to evaluate their transparency on a four-point nominal scale ranging from "criterion not mentioned" to "criterion is met". Buckley, Adams, et al. (2022) subsequently adopted this instrument to code a sample of 38 qualitative studies reported in the *International Journal of Technology and Design Education and Design and Technology Education: An International Journal*. The inclusion criteria were that articles must report an interview-based methodology and be published between 2019 and 2020. The aggregated results for the transparency criteria are shown in Figure 1.

Figure 1. Aggregated transparency levels of 38 interview-based studies in technology education published between 2019 and 2020 (Buckley, Adams, et al., 2022). Scoring codes were (1) "criterion not met", (2) "criterion mentioned but not elaborated", (3) "criterion partially met", (4) "criterion is met", and

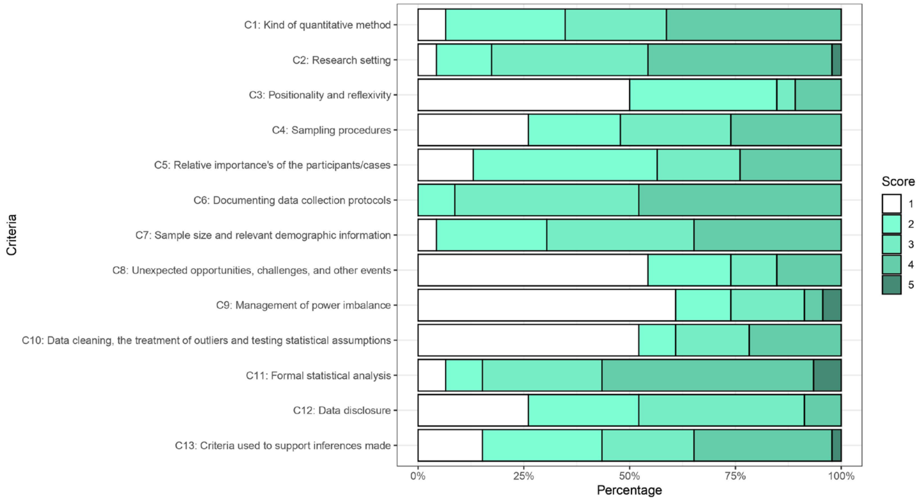
(5) "criterion not relevant". Figure available from https://osf.io/aczbj/?view_only=1459b606c62d4f63b5a8e1d6ea049505.



Subsequent to this, Buckley et al. (2023) adapted the BARS instrument for quantitative research. They conducted a similar analysis where the transparency of a sample of 46 quantitative studies, again from the *International Journal of Technology and Design Education* and *Design and Technology Education: An International Journal* published between 2019 and 2020 were coded. The aggregated results of this study are presented in Figure 2.

Figure 2.

Aggregated transparency levels of 46 quantitative studies in technology education published between 2019 and 2020 (Buckley et al., 2023). Scoring codes were (1) "criterion not met", (2) "criterion mentioned *but not elaborated", (3) "criterion partially met", (4) "criterion is met", and (5) "criterion not relevant". Figure available from https://osf.io/wh735/?view_only=2eae17d333194430a10d2d4c8467d10f.*

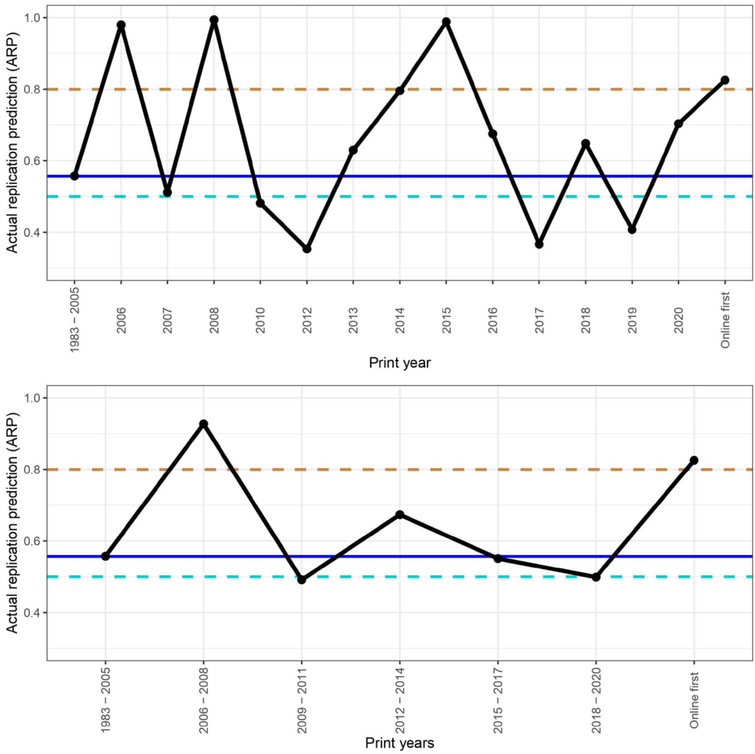


What is immediately clear is that the result distributions from both studies are broadly similar, and across each criterion there are published studies which are not fully transparent which would prevent an exact replication attempt without contacting original authors. Beyond this there are certain aspects of methodologies which researchers, both for quantitative and qualitative studies, tend to not make transparent to a greater degree than others. These included researcher positionality and reflexivity, unexpected opportunities, challenges, and other events, management of power imbalance, data cleaning, the treatment of outliers, and testing statistical assumptions (quantitative studies) and data saturation (qualitative studies). Together, these present guidelines which are immediately translatable into research practice, where authors can be cognisant of transparency and so too can journal reviewers and editors.

3. REPLICABILITY OF TECHNOLOGY EDUCATION RESEARCH

Buckley, Hyland, et al. (2022) examined the replicability of previously published technology education studies using a z-curve analysis (Bartoš & Schimmack, 2020). Replicability refers to the probability that a result in an original study will be observed in an independent replication attempt, which could either be a conceptual or direct replication study. As a goal of quantitative research is typically generalisability, which is in contrast to inductive qualitative research which instead often focuses on transferability, replicability is usually, but not always (cf. Makel et al., 2022), related to quantitative research. It is directly related to statistical power and the sample size of the original study, with a larger sample size reducing the probability of a Type II error (a false negative result) being committed. In their work, Buckley, Hyland, et al. (2022) built upon a previous small-scale examination of technology education research replicability (Buckley et al., 2021) to quantify the replicability rates of quantitative technology education studies from 1983 to 2021 across five relevant academic journals (627 reported statistical tests). The results of their work are presented in Figure 3.

Figure 3.
Actual replication values (ARP) for quantitative studies in technology education (Buckley, Hyland, et al., 2022). Figure available from https://osf.io/zbp5s/?view_only=b9c45f4bf1f54c859bc342de98ece370.



They observed an overall "actual replication prediction" rate (ARP), a prediction of the percentage of results to replicate in actual replication attempts (Schimmack, 2022), to be 55.7%. Interestingly, the ARP from 2009 to 2020 was quite low, the decade previously described as being associated with quite broad empirical studies, whereas for 2021 onwards (indicated by online first articles) where studies have become more explicit the ARP value was much higher (> 80%). This is useful information as it shows both improvement but also indicates a need to examine the validity of findings from the previous decade upon which much current research is being built upon.

4. DISCUSSION ON FUTURE STEPS

Technology education research is maturing and from a number of perspectives and this progression appears to be going in a positive direction. It is important now that as the field continues to grow that good research practices continue to be embedded and become the norm such that the social contract between researchers and the general public is only strengthened. To this end, in addition to ongoing basic and applied research on technology educational phenomena, and to meta-research such as systematic reviews, meta-research on research practices to guide methodological refinement is essential. From the two projects previously described a number of future directions emerge. With respect to transparency, it is not clear whether this has improved over time as both studies were cross-sectional and relate to the same time period. It would be valuable to aim to improve the observed rates such that future publications become more transparent. In line with this, one concept which has not been examined to date in technology education is that of reproducibility. Reproducibility relates to an independent analyst being able to obtain consistent results with an original study using the same input data (Barba, 2018). This requires original study authors to make their original data accessible for reproducibility analyses and is an important dimension to observe the impact of decisions made by researchers (researcher degrees of freedom) on results. Given different researcher positionalities, from an epistemological perspective it would not necessarily be expected to observe consistent interpretations of qualitative studies, and therefore this generally relates to quantitative studies where researchers can share analytic code or analytic steps increasing the transparency of the results and allowing for the robustness of results to be examined.

With respect to building on the prior examination of technology education research replicability, it is immediately apparent that replication studies should be conducted. A big question which needs to be considered though is which previously reported results should be subjects of replication attempts. The z-curve analysis performed by Buckley, Hyland, et al. (2022) only goes so far as to denote average predictions of replicability rates. For example, the overall ARP of 55.7% suggests that 44.3% of published findings would not replicate – but it is not clear which results fall within this 44.3%. Replication attempts of individual studies with adequate sample sizes to give a desired level of statistical power would allow for individual results to be examined. However, such studies would require an investment of effort, both time and financial, and thus a process for determining replication value would be useful within the field. Isager et al. (2020) proposed a formal definition of replication value, inclusive of variables such as the cost in performing a replication attempt, uncertainty about the claim/result before a replication attempt is made, the value of the claim/result, and the expected utility or useful of the claim/result before any replication attempts. Based on this, it would be useful to engage in discourse within the technology education community to contextually define what these variables could mean within the field, and it is likely that this discourse would require input from a broad range of stakeholders such as educators and policy makers to which certain claims or results are relevant. Subsequently, the conduction of formal replication attempts would add significant value to technology education as a practice, with the field's credibility being enhanced and the validity of results being more certain.

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Modelling Approaches to Combining and Comparing Independent Adaptive Comparative Judgement Ranks

Jeffrey Buckley, Technological University of the Shannon, Jeffrey.buckley@tus.ie
Niall Seery, Technological University of the Shannon, niall.seery@tus.ie
Richard Kimbell, Goldsmiths University of London, r.kimbell@gold.ac.uk

ABSTRACT

The use of Adaptive Comparative Judgement (ACJ) for educational assessment addresses one need within technology education for the reliable assessment of responses to open-ended activities which are characteristic within the field. The output of an ACJ session is a rank order of the piece of student work with relative "ability scores". However, the use of ACJ has been limited to date in that ranks are not directly comparable. For example, a rank produced from one class group has no reference information against which to compare a rank produced of the work of another class group. In this type of case a solution has been to combine the work of both classes into one ACJ session, but this has limitation when considering scaling up.

A new goal for the use of ACJ involves solving this issue. The ability to compare or merge ranks presents a new capacity for ACJ – to use a rank as a "ruler" against which other ranks can be compared. In practice this would allow for two possibilities. The first is that a single rank could be developed which presents a national standard against which teachers could compare the work of their students to see where they are performing on a national level. The second is that communities of practice could complete ACJ sessions within their own classrooms, and when meeting as a group they could merge and compare relative performance of their own students to support professional development.

In a previous article a proof of concept of this process conducted via simulation was presented (Buckley and Canty, 2022). In this article we present the results of a project with authentic data – student work completed in response to meaningful activities with teachers acting as ACJ judges – which indicate that the use of ACJ in this way is now possible.

Keywords: Adaptive comparative judgement, assessment, steady state, authentic evidence.

6. INTRODUCTION

The use of adaptive comparative judgement (ACJ) for assessment in technology education was initially proposed and demonstrated through the e-scape project (Kimbell, 2007). The e-scape project aimed to introduce e-portfolios into technology education in a way that would "free learners from the burdens of artificial story-telling and allow them just to get on with their designing" (Kimbell, 2012, p. 136). Within the e-scape project, ACJ then provided an assessment mechanism which would "cancel out" assessors personal standards (Kimbell, 2007, p. 71). ACJ is said to achieve this by having several assessors, or "judges", collectively make binary pairwise comparisons between pieces of student work, or "portfolios, and by collating the decisions of several judges, individual biases are partialled out of the final rank of all work included (cf. Hartell & Buckley, 2021).

Interest in examining the various possible uses and benefits of ACJ for enhancing technology education has grown over the past decade following a special issue on the topic (Williams & Kimbell, 2012), with recent reviews providing an account of the current state of this research endeavour (Bartholomew & Jones, 2022; Buckley et al., 2022). An ongoing agenda is to progress ACJ beyond its current utility, which is limited to individual assessment sessions, and to expand its capacity for national assessment (Seery et al., 2022). This has been a goal ever since it was introduced into technology education (Kimbell, 2012), but recent functional advances are closing this gap (Buckley & Canty, 2022). This paper presents an empirical study which illustrates a new capacity for ACJ, the ability to consolidate and compare unique ranks of student work. Having this capacity would permit the conduction of several, logistically more feasible, small-scale ACJ assessment sessions and then both merging them into a national rank of student work and comparing individual ranks which could represent different geographical jurisdictions. To illustrate a need for this and to contextualise this process, a brief overview of the ACJ method will first be provided.

7. THE METHOD OF ADAPTIVE COMPARATIVE JUDGEMENT

ACJ ultimately involves having several judges collectively produce a rank order for a collection of portfolios which describes the relative best to relative worst pieces of work. Initially, a sample of portfolios and cohort of judges are identified. Typically, the process from this point is managed by propriety software (e.g. RM Compare, 2023) where the portfolios are digitised and judges are given individual accounts. The session begins with the portfolios being randomly paired together, with individual pairs being presented to judges. Each judge then makes a binary decision of which portfolio is "better" or "worse". At least in technology education, this decision has typically been made on a holistic construct of capability (e.g. Seery et al., 2019) with judges being shown to make decisions on varying criteria which are personally selected (Buckley et al., 2020), although formal criteria could be used. After a designated number of judgements are made through a Swiss tournament system[6], an adaptive algorithm is initiated to manage the pairing of portfolios. This

[6] For the Swiss tournament, in the first round portfolios are randomly paired together for comparison. The result will be half of the portfolios having 1 winning result, and the other half having 0 winning results. In

is a defining characteristic separating comparative judgement (CJ) from ACJ. The adaptive algorithm pairs portfolios based on which pairings provide the most information in terms of generating the rank. At the end of the session, which can be determined in several ways such as when a certain level of reliability is achieved or after a prescribed number of judgements (e.g. Verhavert et al., 2022), the decisions from each judgement are used to fit a Bradley-Terry-Luce (BTL) model, which generates a rank order of the portfolios included in the session. The BTL model is computed by

$$\alpha_i = \frac{W_i}{\sum_{j \neq i} \frac{w_{ij} + w_{ji}}{\alpha_i + \alpha_j}} \quad (1)$$

where i and j are individual portfolios, W_i is the total number of wins of portfolio i, w_{ij} is the number of wins portfolio i has against portfolio j, w_{ji} is the number of wins portfolio j has against portfolio i, α_i is the ability score estimate of portfolio i, and α_j is the ability score estimate of portfolio j (Hunter, 2004). Initially, all ability scores are estimated as 1 and then normalised to maximum likelihood estimates.

Importantly, the rank does not provide any absolute indicators of quality. Performance is denoted in “parameter values” or “ability scores” which are centred around 0 (i.e., a score of 0 represents the theoretical average portfolio, with positive scores being above average and negative scores below average). Taking the top and bottom ranked portfolios as an example, once the rank is generated there is still no determination whether either is “good” or “poor” in terms of absolute performance. The entire rank could represent outstanding work, it could all be very poor-quality work, or it could range from anywhere in between. A process beyond the ACJ session is required to map the rank onto, for example, grades which could denote performance. The rank is limited to relative performance indication where the quality of any individual portfolio is only presented as a relative value in comparison to all other portfolios in the rank. This presents a significant limitation in that if two independent ranks are generated, both will have a mean ability score of 0 and within-rank relative ability scores, but these scores are not immediately comparable between ranks. As such, independent ranks cannot be consolidated or compared directly without an additional procedure where they are adjusted onto the same scale. The paper presents a study where three approaches to scaling ranks are explored to alleviate this current limitation.

8. METHOD

Four ACJ sessions were conducted as part of this study. The first three of these were typical ACJ sessions managed through the RM compare (2023) system where the portfolios were paired

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the subsequent rounds, portfolios are again randomly paired but now only with those which have the same or a similar number of wins as they have. Thus, during the second round for example, portfolios with 1 win after round one are paired randomly with other portfolios with one win, whereas those with 0 wins are paired with others which also have 0 wins. The outcome of round two being a selection of portfolios with 2 wins, 1 win, and 0 wins. This process then repeats for the designated number of rounds, with no portfolios being paired together more than once.

initially by a Swiss tournament system and then by an adaptive algorithm as previously described. These are herein referred to as Session A, B, and C respectively. The fourth ACJ session (herein Session D) utilised a novel adaption to the RM Compare platform where pairs could be manually determined in advance of the session and assigned to specific judges. In total, there were 13 judges who were all technology education educators at either secondary level or in higher education on technology teacher education programmes, and 35 portfolios which were generated in response to an authentic task by secondary level technology pupils. The portfolios were generated by pupils in two schools, School A and School B. Pupils in School A submitted 17 portfolios with 18 portfolios being submitted from School B. The task was a classroom-based assessment (CBA) which is a new introduction to the Irish lower-secondary school system (Department of Education and Skills, 2015). Twice in students' lower secondary education they must complete a CBA which is then assessed by their teacher for formative purposes only. The results of these are indicated in students' Junior Cycle Profile of Achievement (JCPA), a record of their overall performance at lower secondary level. The task completed by all students was an investigation into "The ergonomics of household objects" and it was a CBA assigned nationally to all students taking the technology subject of Graphics. While responses to a national assessment, no data were collected to provide an indication as to whether the portfolios collected in this study were nationally representative.

All 13 judges participated in each of Session A, B, and C, and the portfolios were assigned to each session as shown in Table 1. Note that portfolios submitted from School A received an anonymous ID in the format portfolio.aX and portfolios submitted from School B received an anonymous ID in the format portfolio.bX.

Table 1. Portfolio ID's and list of portfolios included in Sessions A, B, and C.

Portfolio No.	Portfolio ID	Session A portfolios	Session B portfolios	Session C portfolios
1	portfolio.a1	●		●
2	portfolio.a2	●		●
3	portfolio.a3	●		●
4	portfolio.a4	●		●
5	portfolio.a5	●		●
6	portfolio.a6	●		●
7	portfolio.a7	●		●
8	portfolio.a8	●		●
9	portfolio.a9	●		●
10	portfolio.a10	●		●
11	portfolio.a11	●		●
12	portfolio.a12	●		●
13	portfolio.a13	●		●
14	portfolio.a14	●		●
15	portfolio.a15	●		●
16	portfolio.a16	●		●
17	portfolio.a17	●		●
18	portfolio.b1		●	●
19	portfolio.b2		●	●
20	portfolio.b3		●	●

Portfolio No.	Portfolio ID	Session A portfolios	Session B portfolios	Session C portfolios
21	portfolio.b4		●	●
22	portfolio.b5		●	●
23	portfolio.b6		●	●
24	portfolio.b7		●	●
25	portfolio.b8		●	●
26	portfolio.b9		●	●
27	portfolio.b10		●	●
28	portfolio.b11		●	●
29	portfolio.b12		●	●
30	portfolio.b13		●	●
31	portfolio.b14		●	●
32	portfolio.b15		●	●
33	portfolio.b16		●	●
34	portfolio.b17		●	●
35	portfolio.b18		●	●

The outcome of each session was a rank order of the included pieces of work, and the rank reliability is denoted by the scale separation reliability (SSR) coefficient computed by

$$SSR = \frac{\sigma_{\alpha}^{2} - MSE}{\sigma_{\alpha}^{2}} \qquad 2$$

where σ_{α}^{2} is the standard deviation of the estimated ability scores squared, and MSE is the mean squared standard error, or the mean of the standard error values after they have been squared. The results for each of these sessions are presented in Figure 1, Figure 2, and Figure 3 respectively.

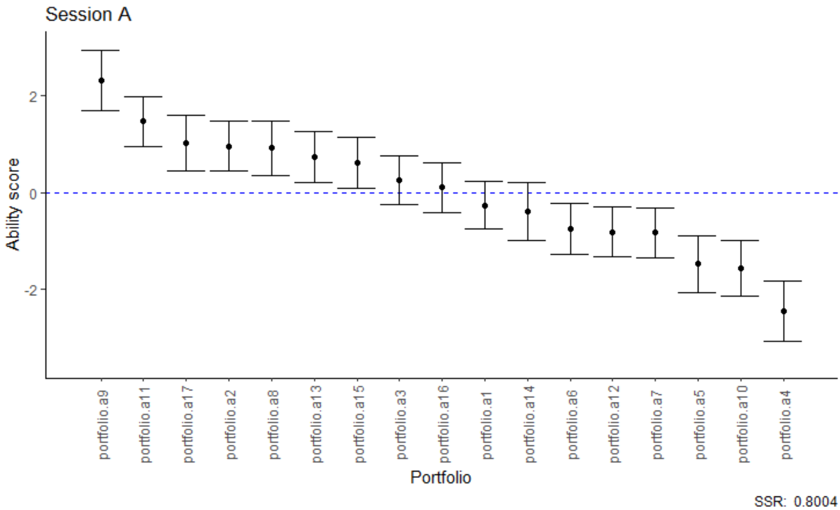

Figure 1. Session A ACJ rank.

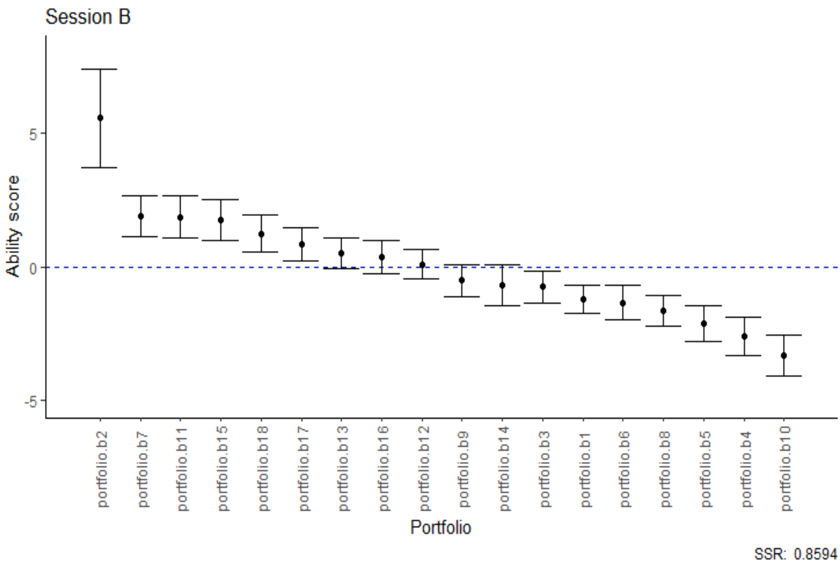

Figure 2. Session B ACJ rank.

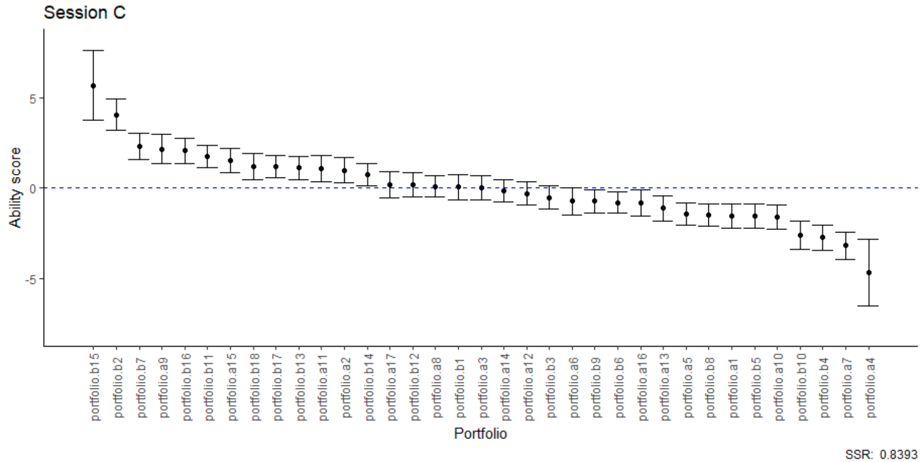

Figure 3. Session C ACJ rank.

Each rank achieved a high level of reliability (SSR > .8). They were also generated with each having a different purpose. The resulting rank from Session C represents a goal state. It contains a single rank containing all portfolios generated through comparative judgements from the judge cohort. It is highly reliable (SSR = .839) and immediately permits the relative performance of School A to be compared with the relative performance of School B. Session's A and B represent separate performance ranks for School A and School B, and in their current states are not immediately comparable nor can they be merged into a single rank. As such, Session D was designed to merge the ranks from Session A and Session B, with the resulting merged rank being compared with that from Session C to see how well the merging process worked. More specifically, three approaches to achieving this were examined and are referred to as Model D1, D2, and D3. In each case, the rank produced from Session B will act as analogous to a proposed "ruler" or steady state concept (Seery et al., 2022). That is, this rank will be fixed, and the achievement of the project aims involve the successful merging of this rank with the rank produced from Session A. As such, the rank from session A will be adjusted through a scaling process to situate it comparably into the rank produced from Session B.

Each of the approaches for Model D1, D2, and D3 followed the same overall process:

1. Select a portfolio(s) from the Session A rank to "judge into" the rank from Session B.

2. Select the portfolios from the Session B rank against which the selected Session A portfolio(s) would be judged.

3. A purposefully selected sample of the original 13 judges would complete the judgements of the portfolios selected in Step 1 and Step 2.

4. Using the judgements from Step 3, produce a rank using the BTL model. In this rank, the "parameter values" or "ability scores" of the portfolios selected from the Session B rank would be fixed to those which were produced through Session B, and thus only the parameter values of the Session A portfolios are recomputed. These recomputed Session A portfolio parameter values would therefore represent the positioning of the selected Session A portfolios within the Session B rank.

5. Using the recomputed parameter values of the selected Session A portfolios, take the judgements made from the original Session A rank, and recompute the entire Session A rank, this time with the recomputed parameter values of Session A portfolios from Step 4 being fixed. This would produce a completely recomputed Session A rank, with parameter values now scaled relatively to those from Session B.

6. Merge the recomputed Session A rank from Step 5 with the original Session B rank.

7. Compute a correlation coefficient from the merged rank from Step 6 with the original Session C rank.

This procedure requires the selection of judges (Step 3) to make the new judgements. These were selected by first getting the mean misfit statistic for each judge based on Session A and Session B. Judges were then ranked based on the absolute difference between their average misfit and 1 (Table 2). Model D1 needed one judge (judge 2 was used). Model D2 needed three judges, (judges 12,7 and 11 were used). Finally Model D3 also needed three judges (judges 3,1, and13 were used). All judgements which were required (described below in Table 3, Table 4, and Table 5) were run through the single Session D which permitted the manual selection of judgements to be made.

Table 2. Judge ranking based on average misfit from Session A and Session B.

Judge	Session A misfit	Session B misfit	Absolute difference between 1 and average misfit
judge.2	0.797566	1.253231	0.025398
judge.12	1.045002	1.093468	0.069235
judge.7	1.076206	1.112101	0.094153
judge.11	0.88119	1.342626	0.111908
judge.3	1.256328	1.006778	0.131552
judge.1	0.679718	0.819701	0.25029
judge.13	0.760399	1.794187	0.277293
judge.5	1.304007	0.138742	0.278625
judge.6	1.603682	0.972127	0.287904
judge.9	0.72778	0.676694	0.297763
judge.10	1.560905	1.419284	0.490095
judge.4	0.704051	0.18031	0.55782
judge.8	0.26236	0.473132	0.632254

9. RESULTS

9.1. Model D1

For this model, the middle (median) portfolio from Session A (Figure 4) was compared to each portfolio in Session B in a random order (Table 3). These decisions represent steps 1-3 from the previously described process. Next, the previously described steps 4 to 6 were completed, which resulted in a recomputed parameter value for portfolio.a16, which was used to scale the resulting Session A portfolio parameter values and then merge these into the original Session B rank. The resulting Pearson (linear/parametric) and Spearman (monotonic non-linear/non-parametric) correlation coefficients between this merged rank and original Session C rank were $r = .82$ [95% CI; .67, .91], $p < .001$ and $\rho = .86$ [95% CI; .74, .93], $p < .001$ respectively, which are very strong, and they resulted from a single linked portfolio and a single judge.

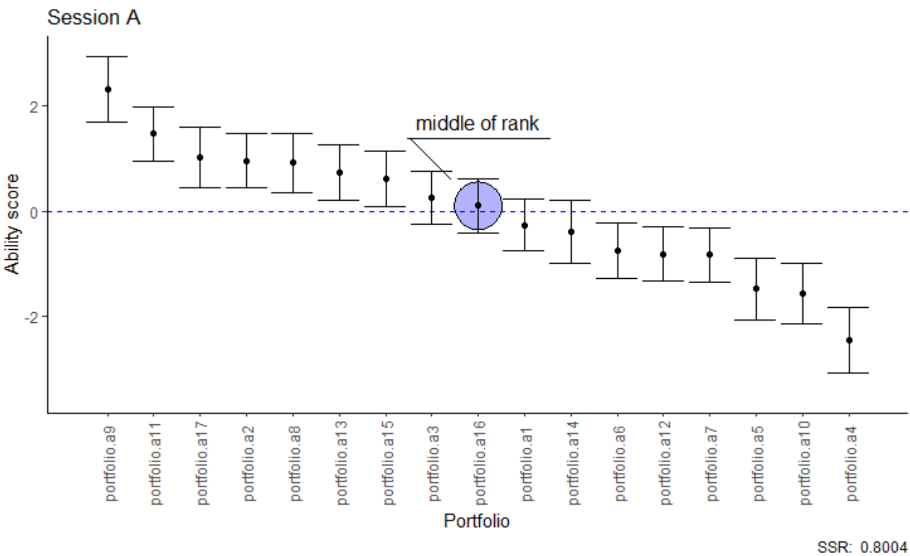

Figure 4. Model D1 Session A rank portfolio selection.

Table 3. Model D1 comparisons in order.

Session B portfolio	Compared Session A portfolio by judge.2
portfolio.b5	portfolio.a16
portfolio.b18	portfolio.a16
portfolio.b6	portfolio.a16
portfolio.b12	portfolio.a16
portfolio.b13	portfolio.a16

Session B portfolio	Compared Session A portfolio by judge.2
portfolio.b1	portfolio.a16
portfolio.b14	portfolio.a16
portfolio.b15	portfolio.a16
portfolio.b10	portfolio.a16
portfolio.b3	portfolio.a16
portfolio.b17	portfolio.a16
portfolio.b2	portfolio.a16
portfolio.b11	portfolio.a16
portfolio.b16	portfolio.a16
portfolio.b4	portfolio.a16
portfolio.b7	portfolio.a16
portfolio.b9	portfolio.a16
portfolio.b8	portfolio.a16

9.2. Model D2

Following this, we hypothesised that comparisons from a larger number and spread of portfolios in the Session A rank with portfolios from Session B might improve the correlation of the merged rank with that from session C. For Model D2, the top (relative best), middle (median) and bottom (relative worst) portfolios from Session A (Figure 5) were compared to the random sample of portfolios from Session B (Table 4). The process then proceeded identically to that of Model D1. The resulting Pearson and Spearman correlation coefficients were r = .48 [95%; .18, .70], p = .003 and ρ = .47 [95% CI; .15, .70], p = .005 respectively. These are strong correlations however they are markedly weaker than those from Model D1. Given the wider confidence intervals of portfolios at the extreme tails of the rank (portfolio.a9 and portfolio.a4), it is theorized that this result stems from the lower certainty of the positions of the relative best and relative worst portfolios in a rank. By representing the extremes, they do not have portfolios beyond them in the Session A rank which provide relative information of by how much they are the best and worst in the rank. The re-computation of the original Session A portfolios using these portfolios therefore likely introduced additional error due to the higher degree of uncertainty/higher error associated with these portfolios.

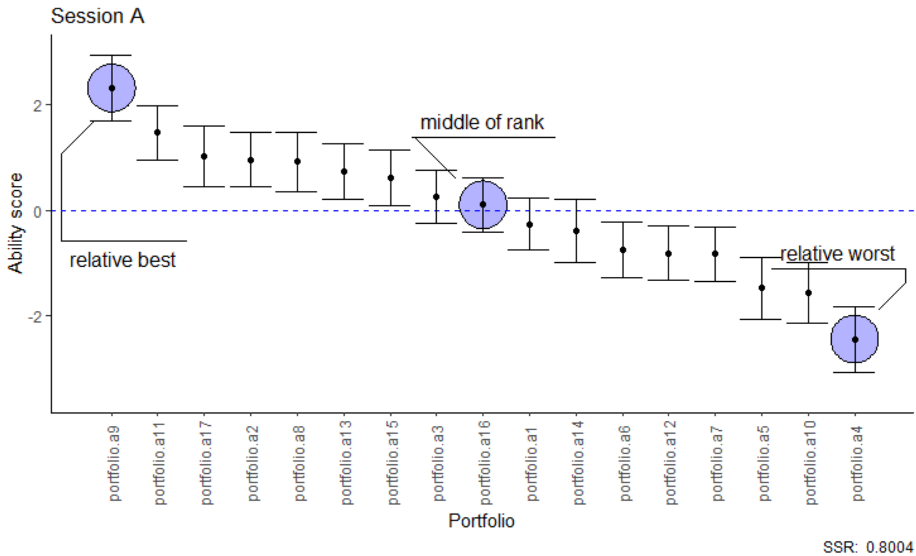

Figure 5. Model D2 Session A rank portfolio selection.

Table 4. Model D2 comparisons in order.

Session B portfolio	Compared Session A portfolio by judge.12	Compared Session A portfolio by judge.7	Compared Session A portfolio by judge.11
portfolio.b16	portfolio.a9	portfolio.a4	portfolio.a16
portfolio.b5	portfolio.a9	portfolio.a4	portfolio.a16
portfolio.b12	portfolio.a9	portfolio.a4	portfolio.a16
portfolio.b15	portfolio.a9	portfolio.a4	portfolio.a16
portfolio.b9	portfolio.a16	portfolio.a9	portfolio.a4
portfolio.b17	portfolio.a16	portfolio.a9	portfolio.a4
portfolio.b6	portfolio.a16	portfolio.a9	portfolio.a4
portfolio.b4	portfolio.a16	portfolio.a9	portfolio.a4
portfolio.b2	portfolio.a4	portfolio.a16	portfolio.a9
portfolio.b7	portfolio.a4	portfolio.a16	portfolio.a9
portfolio.b18	portfolio.a4	portfolio.a16	portfolio.a9
portfolio.b10	portfolio.a4	portfolio.a16	portfolio.a9

9.3. Model D3

Based on the results of Model D2, to avoid using portfolios from the extremes of the Session A rank, three portfolios down from the top and up from the bottom, and also from the middle were selected from the Session A rank (Figure 6) to merge into the rank from Session B (Table 5). The aim here was to reduce the error introduced by using portfolios at the extreme ends which we believed introduced greater error. With this approach, we build in more information than Model D1, but the relative best and second best and relative worst and second worst mean there are portfolios now on either side of all selected portfolios from Session A which provide additional information regarding relative positioning. The resulting Pearson and Spearman correlation coefficients were $r = .79$ [95% CI; .62, .99], $p < .001$ and $\rho = .80$ [95% CI; .64, .90], $p < .001$. These results are not significantly different from those of model D1 despite the additional information for the rescaling of the Session A rank.

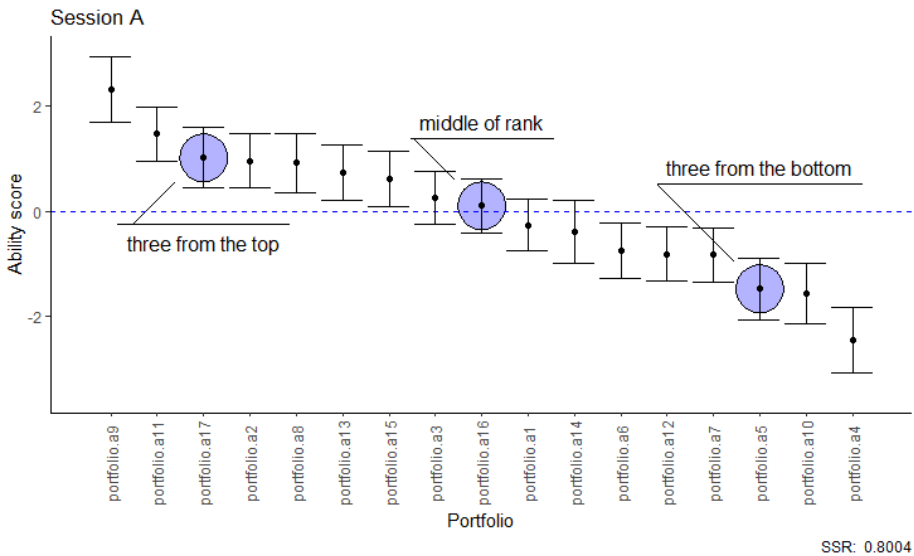

Figure 6. Model D3 Session A rank portfolio selection.

Table 5. Model D3 comparisons in order.

Session B portfolio	Compared Session A portfolio by judge.3	Compared Session A portfolio by judge.1	Compared Session A portfolio by judge.13
portfolio.b16	portfolio.a17	portfolio.a5	portfolio.a16
portfolio.b5	portfolio.a17	portfolio.a5	portfolio.a16
portfolio.b12	portfolio.a17	portfolio.a5	portfolio.a16
portfolio.b15	portfolio.a17	portfolio.a5	portfolio.a16
portfolio.b9	portfolio.a16	portfolio.a17	portfolio.a5

Session B portfolio	Compared Session A portfolio by judge.3	Compared Session A portfolio by judge.1	Compared Session A portfolio by judge.13
portfolio.b17	portfolio.a16	portfolio.a17	portfolio.a5
portfolio.b6	portfolio.a16	portfolio.a17	portfolio.a5
portfolio.b4	portfolio.a16	portfolio.a17	portfolio.a5
portfolio.b2	portfolio.a5	portfolio.a16	portfolio.a17
portfolio.b7	portfolio.a5	portfolio.a16	portfolio.a17
portfolio.b18	portfolio.a5	portfolio.a16	portfolio.a17
portfolio.b10	portfolio.a5	portfolio.a16	portfolio.a17

10. DISCUSSION

The results of this work are promising in that through this project previously unique ranks which were internally relative were successfully merged. This opens up considerably more functionality for ACJ both for large scale assessment and research purposes as comparative work is now more possible. By supporting comparisons between ACJ ranks of student work, this functionality could also benefit professional development for teachers as they could see and discuss how students work is comparable on larger scales than before. The merging of ranks required additional comparisons to be made, which were managed through a more controllable version of ACJ developed by RM Compare, and working with the BTL model outside of existing ACJ software systems. It should be noted that this project could also have been designed such that rather than scaling the Session A rank to fit into the Session B rank which remained fixed, both the original Session A and Session B ranks could have been merged by fitting the BTL model to the original judgements of both ranks with the new judgements in a single step. This would have meant that both original ranks would have been adjusted. This may be a valuable approach to take in the future, however for this project by fixing one rank in place we demonstrate the functionality not only to merge and thus compare disparate ranks, but also to track relative changes over time by keeping historic ranks fixed for comparability purposes. While the study was exploratory, it appears that working with portfolios at the extremes is not an optimal approach. As such, while future confirmatory studies are important, as this project scales to larger sample sizes where more models can be explored, focusing on portfolios with lower standard error values seems like a strategic choice.

11. ACKNOWLEDGMENTS

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Supporting Initial Teacher Education Students Assessment Literacy and Capability Development.

Donal Canty, University of Limerick, donal.canty@ul.ie
Nicolaas Blom, University of Limerick, nicolaas.blom@ul.ie
Sean O'Connor, University of Limerick, sean.oconnor@ul.ie
Maria McCarthy, University of Limerick, maria.mccarthy@ul.ie

ABSTRACT

Recent curricular reform in Ireland has utilised classroom-based assessments as part of the national assessment strategy at the junior level in post-primary education. This calls for teachers to exercise their judgement in relation to their pupils' capability which is recorded for the certified national award of the Junior Cycle Profile of Achievement (JCPA). Ensuring effective assessment in this regard requires the development of assessment literacy and capability in the teaching cohort that commences on the continuum of teacher development at the initial teacher education (ITE) phase. Teacher judgement in assessment is reliant on multiple factors that impact on the assessment outcome. It is therefore important to design components of ITE programmes that provide opportunity to strategically develop this capability for implementation in practice. This case study presents an initial analysis of the practices and experiences of (n=87) Initial Teacher Education (ITE) students as they engage in a peer assessment activity that is part of an assessment literacy and capability development strategy on a technology education ITE programme. This was facilitated through the use of Adaptive Comparative Judgement sessions (ACJ). In these sessions, the participants engaged in the establishment of assessment criteria and implemented them in the holistic assessment of peers' work through the ACJ method along with providing formative feedback and making a summative judgement of the quality of the work. The findings present the usefulness of ACJ in providing pre-service teachers a space to develop assessment literacy and capability through the active and experiential learning approach taken.

Keywords: Assessment literacy, Assessment Capability, Adaptive Comparative Judgement

1. INTRODUCTION

The nature and instruments of assessment in schools are experiencing significant change. Such change brings with it the need for teachers to have the literacy and capability associated with assessment to ensure accountability, fairness and purposeful utilisation of assessment as part of their teaching and learning strategies. Recent reform in Irish curricula have emphasised the important role assessment plays in learning and teaching where significant emphasis is placed on formative assessment as a means to support learners' development and progression. This is evident in the introduction of classroom-based assessments (CBAs) that are intended to be formative in nature but also have a summative role as they are used to give a snapshot in time of the learners' capability that is recorded on the Junior Cycle Profile of Achievement (JCPA) which is a national award at the end of the junior cycle of learning (12 to 15 year old students). For the first time, this approach sees teachers in Ireland being part of the national assessment framework through their work and practice in their everyday classroom activities. With this new approach it is critical that the teaching body have the relevant knowledge, skills and dispositions to ensure the intentions of the curriculum and its associated assessment architecture are achieved. The capacity to integrate and use assessment in the classroom to facilitate and evaluate student learning is at the heart of teacher's assessment literacy and capability (Popham, 2004; Popham, 2009; Brookhart, 2011; Xu and Brown, 2016; DeLuca and Johnson, 2017). The journey to the acquisition of these skills begins with the initial teacher education programmes that prepare student teachers for their lifelong journey through the teaching profession. It is accepted that historically assessment literacy development has been poorly addressed in teacher education programmes. (Stiggins, 1999; DeLuca et al., 2013; Xu and Brown, 2016). Within the Irish context, this limitation has received a renewed focus with the publication of CÉIM standards for Initial Teacher Education in Ireland (Teaching Council, 2020). The standards send a clear message in relation to the development of assessment literacy where they emphasise that:

> "Student teachers shall be supported in their development of strategies to support, monitor and holistically assess pupils' approaches to learning and their progress – including effective feedback techniques".

To achieve this goal and meet the standards, ITE providers must strategically integrate the development of assessment literacy and capability over the duration of the programmes of study to achieve accreditation status to graduate student teachers. With this purpose in mind, this paper presents a pedagogical approach that was implemented in the third year of a four-year undergraduate initial teacher education programme to develop assessment literacy. The approach was implemented in a subject discipline specific pedagogy module where there are specific learning outcomes relating to assessment literacy and capability development.

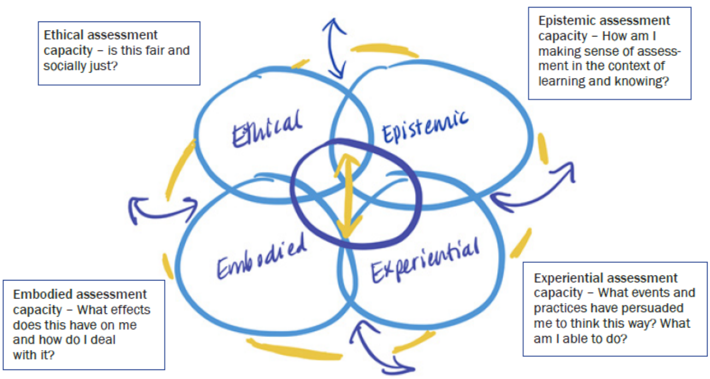
2. ASSESSMENT LITERACY DEVELOPMENT IN ITE

The treatment of assessment literacy and capability development in teacher education programmes has been neglected and has had an *ad hoc* level of integration as part of the student teacher learning experience (Xu and Brown, 2016). However, the role of assessment as part of the learning process has become much clearer through contemporary research (Black and Wiliam 1998; Hattie & Timperley, 2007; Sadler, 2009; Schellekens et al., 2021; Hattie, 2023) and thus the need for teachers to become more skilled in relation to assessment is amplified. But assessment is a complex area and in a constant state of flux, responding to policy, school environment and global trends that necessitate the need for ITE providers and student teachers to learn about and embrace multiple purposes and practices of assessment in schools (DeLuca and Bellara, 2013).

With a greater understanding of the role of assessment in teaching and learning, the area of assessment literacy development has been an increasing area of interest with many models and approaches presented in the literature. For this paper we adopt the view of Willis et al (2013, p. 242) who view assessment literacy as "a dynamic context-dependent social practice that involves teachers articulating and negotiating classroom and cultural knowledges with one another and with learners, in the initiation, development and practice of assessment to achieve the learning goals of students". We differentiate assessment literacy from assessment capability as the latter focuses on the enactment of the "know how" assessment literacy in practice from the teacher's perspective. Coombs and DeLuca (2022) explain that assessment capability focuses on the student and their interaction with the teacher to support their current and future learning as opposed to assessment literacy that focuses primarily on the teacher.

Canty et al. (2022) presented an approach to assessment literacy development based on the conceptual framework by Xu and Browne (2016) that highlights the importance of an appropriate knowledge base for the development of assessment literacy. However, it is acknowledged that a strong knowledge base alone is not sufficient for assessment literacy and for effective transfer into capability in practice. Furthermore, teacher beliefs and experiences of assessment have a significant impact on the development of assessment literacy and capability. Deeply rooted conceptions of assessment that are formed from experiences of assessment in school, such as the dominance of summative practices, can negatively impact on developing the ITE student teachers' assessment literacy (Xu and Browne, 2016). Indeed, the multiple challenges to assessment education in initial teacher education programmes are presented by DeLuca and Johnson (2017). With this evident it is critical that ITE programmes develop more strategic approaches to assessment literacy and capability development such that their experiences through the initial years of teaching in schools has a solid foundation to help them interpret and shape their approach to assessment. To address this Willis et al. (2022) present four capabilities that emerged as common to teachers from four countries, Canada, New Zealand, Australia and England. The four assessment capabilities in Figure 1 are presented as dimensions that underpin a beginning teachers assessment decision making.

Figure 1: Four Assessment Capabilities (Willis, DeLuca, Harrison, Cowie, 2022)



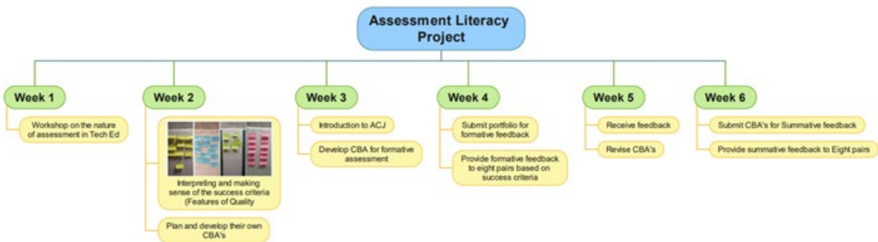
The model proposes that these dimensions provide a basis for a beginning teacher to think and communicate their reasoning in relation to assessment decisions. These dimensions provide opportunity for student teachers and academics to examine their assessment decisions and to gain insight into how they are processing their newly emerging knowledge and skills. It is therefore important that initial teacher education programmes are designed to address assessment literacy and capability development and should provide opportunity for these dimensions to be experienced and explored as part of the initial teacher education experience.

What is clear from the current research is that assessment literacy development is more than the mere acquisition of knowledge and skills in relation to assessment. Teachers' developing professional identities have a significant impact on the implementation of assessment knowledge in diverse contexts of learning. If we view assessment knowledge as independent of other knowledge relevant to teaching and learning then the potential scope of assessment of, for and as learning may not be recognised or achieved. This paper will present how an assessment literacy and capability development task, delivered in a technology subject specific pedagogy module provided opportunity for student teachers to learn and experience assessment across the four capabilities of Ethical, Epistemic, Embodied and Experiential.

3. APPROACH

This study was implemented in a subject discipline specific pedagogy module with learning outcomes relating to assessment literacy and capability development. The approach was influenced by the four assessment capabilities presented by Willis et al. (2022) and by the conceptual framework of teacher assessment literacy in practice (TALiP-model; Xu and Brown, 2016). The module of study was designed to provide experiences and opportunities for student teachers to explore and develop each of the areas of capability through the medium of a learning and assessment task informed by the national curriculum for technology education in Ireland. The task was facilitated through the use of Adaptive Comparative Judgement (ACJ) which was integrated to act as a catalyst and medium for decision making in relation to assessment that are core to assessment capability. An outline of the approach is presented in Figure 2.

Figure 2: A six-week unit on developing assessment literacy



As part of the ACJ process judges are presented with a pair of assessment portfolios or scripts. They use relevant criteria as their basis for their judgement of each portfolio and then pick a winner from the paring based on the portfolio they think is better. The collective aggregation of all the judgements by judges on the portfolios then creates a rank order of quality of the work within the judging session as determined by that judging cohort. The participants (n=87) were in their third year of a four-year concurrent Technology Education initial teacher education programme. As part of the learning and assessment strategy in the module, student teachers created a sample CBA task that followed the guiding principles for assessment set out by the curriculum. At an intermittent stage in the development of the CBA task participants completed an ACJ session that was formative in nature where in their role as judges they practiced giving feedback to their peers on their work to date. Following this they had a further week to develop their work for final submission. After submission they completed another ACJ session but this time the assessment was more summative in nature where student teachers had to identify how the work addressed the features of quality associated with the task and benchmark it to the levels of attainment for the CBA i.e. Yet to meet expectations, In line with expectations, Above expectations or Exceptional. On completion of the ACJ sessions students completed a reflective activity through an electronic open-ended questionnaire that captured their experience and reaction to the CBA assessment task. Data analysis followed Clarke et al. (2015) guidelines for conducting thematic analyses.

4. FINDINGS AND DISCUSSION

For the purposes of this paper, the focus is on student teacher reflections and how they relate to the four capabilities presented in Figure 1. The data analysis is in its early stages and thus this will be a broad overview of how the approach created the opportunity for students to engage with and experience aspects of assessment that relate to the four capabilities of Ethical, Epistemic, Embodied and Experiential. The approach taken in the study used ACJ and peer assessment as a central medium for students to experience assessment both from the perspective of an assessor (teacher in class) and a learner. The participants created an assessment output in response to a typical CBA assessment task where they interrogated the features of quality (criteria) from the perspective of a learner. They provided peer feedback at the midpoint of the task to help learners progress their work and at the end of the task to help learners to focus on what they need to work on for future learning. During this time the student teachers were also learning about the nature and role of feedback in learning and used ACJ activities to critically reflect on both the feedback that they gave (teacher perspective) and that they received (learner perspective). In the second ACJ session the students also had to benchmark the work using the national standards and features of quality. These standards and features of quality are the instruments available to teachers when they evaluate and assess their students CBAs in practice for their JCPA award. This required the student teachers to make decisions on the level of work being assessed drawing on their emerging construct of quality in relation to capability in the subject discipline.

4.1. Experiential assessment capacity

The ACJ activities were a catalyst for discussion in tutorials and lectures throughout the semester with many dilemmas experienced by the students being resolved through analysis of their actions or lack of them. The following are some indicative comments that support this:

> My thoughts on making judgments on my peer's work was quite unusual. I felt my feedback given early on in the semester was very poor. Until this module we had gone into detail on summative and formative feedback, I know the cons and pros and when to use each one, but I realised after giving feedback I was poor at actually doing it. I was looking back at my feedback being one or two sentences long. It also occurred to me I will be giving a lot of feedback to students next semester (on school placement), so it is an area that needs immediate work. (Participant 19b)

> This replicated a classroom scenario. I was also able to see where my own ability to give feedback was at and how much I had learned from labs earlier on in the module as we had done activities to come up with our own descriptors for the features of quality. (Participant 7a)

> I began to understand how my feedback could help the student to learn and develop. I sat myself into the student's shoes and imagined what feedback would I like to receive and in what way would I find it easiest to decipher and make use of the feedback. (Participant 20a)

These comments indicate that the approach impacted on the student teachers as they reflected on their development as a teacher because of the approach in the module of study. The experience of having to complete a live assessment task, giving feedback that was received and interpreted by learners and making an evaluative judgement that would contribute to the rank order of quality were all significant experiences for the student teachers in the module. This helped them grapple with new ideas in relation to assessment and project forward to how they may approach assessment with their own classes in the school setting.

4.2. Ethical assessment capacity

Teachers need to be aware of the ethical responsibilities that they have in relation to assessment. Xu and Browne (2016) highlight how teachers are required to know how to work towards equity, non-discrimination, inclusion, and social justice. The ethical issue came to light early on in the peer assessment activity as the work was not anonymised. This was purposeful as these student teachers need to become used to assessing their own pupils in the future which may include their own children, the children of colleagues, friends, neighbours etc. This provides an ethical dilemma around equity, fairness and bias in their judgements. The following are some indicative comments from the student teachers in relation to this issue:

> I also found it strange when I had to correct a CBA belonging to someone I am friends with but I had to be honest and give all of the CBA's a fair trial without being biased. (Participant 4a)

> Grading peers work can be challenging, particularly those whom you may be friendly with. I feel as though I managed to avoid grading with bias which is something I am pleased about. (Participant 15a)

> The experience of making judgments on my peer's CBAs was quite a complex process and it required me to be careful in my considerations and not be biased in my approach, I found it more difficult when trying to give completely unbiased feedback to friends of mine but made my best attempt at looking at their work for the work alone. (Participant 22a)

While the majority of examples in relation ethical issues related to evaluating the work or friends the process did raise the issue of bias and personal decisions that could impact on the validity of assessment. In some instances, the students had to evaluate their own work (Participant 40a) against the work of one of their peers and decide on which piece of work was better. These experiences and dilemmas are helpful in preparing student teachers for classroom-based assessments of their own pupils.

4.3. Epistemic assessment capacity

This aspect of assessment capability relates to student teachers making sense of assessment as part of learning and knowing (Willis et al. 2022). At times the participants reflected and questioned themselves (Participants 13a and 46a) where they begin to see the power of peer assessment as part of a pedagogical strategy to support learning.

> One of the things I found quite interesting about the judging process was the broad range of mixed ability within the class. This was something I was aware of from my school placement as I had to cater for mixed ability in my lessons day-to-day. Because I had much younger students, their learning was not as autonomous as us, third level students, and therefore my perception of mixed ability was different prior to this judging session. By engaging with this activity, I have come to realize just how varied mixed ability can be and especially when learners are given lots of autonomy. (Participant 13a)

> Seeing the aspects of my peers work that I feel were better than mine as well as some creative ideas I never even thought about implementing showcased to me the multiple possibilities that 1 assignment can achieve. I then pondered on how similar this was to my previous school placement of assessing my students work and the many different ways my student interpreted the information I had given them to produce an assignment. I will aim to utilise this experience of peer assessment to better my own abilities in assessing student knowledge in my next school placement. (Participant 46a)

Other participants showed evidence of recognising the importance of rubrics and criteria in forming their judgements but acknowledged that how they are interpreted and actioned needs to be practiced and developed. They also experienced the challenge of assessing different approaches to the same assessment task and using the features of quality to form their judgement. Some student teachers struggled with this as in the example of Participant 30b.

> By giving feedback to my peers using the ACJ process I felt as though I improved my understanding of the features of quality and what underpins each feature. (Participant 13a)

> Personally, I think that the most important take away from this activity is starting to build on my own ability to make accurate assessment judgements, and the only way to get better at this is to get exposure to a range of different samples and the features that enhanced them. (Participant 33a)

> I found the overall experience a difficult task following the features of quality and assessing each CBA in line with the features of quality. I found myself trying to identify whether or not the criteria was met to award one descriptor over another. (Participant 30b)

4.4. Embodied assessment capacity

It is acknowledged that assessment is an activity that will impact on the emotions of both learners, teachers, parents, school leaders etc. It is evident from the student reflections that this was experienced during the module of study. Many participants referred to how difficult or time consuming it was to engage with the process meaningfully but indicated that it was important to do so. It was also evident that they wanted to help learners progress through their feedback, and they worked to ensure that the quality of their feedback improved in the second judging session. They were also conscious of the impact that their feedback may have on the learners and sometimes struggled with the best way to communicate their message such that it would not demotivate or upset the recipient. Some indicative comments from participants reflect this:

> I found the overall experience very exhausting and hard. I found that it is easy to give the positive feedback on what the student has completed, but I found it hard to provide appropriate wording of the feedback when I identified the weakest elements of the CBA without being overly harsh because I don't want to knock someones confidence. (Participant 24a)

> On a personal level as someone who holds myself to quite high standards I did question as to the level of work I was expecting from my peers and wonder if I was being too harsh in cases. (Participant 15a)

Conclusion

The analysis of the data from this study is in its early stages and this paper gives just a snapshot of the initial analysis. The work hopes to inform future innovations in the development of assessment literacy and capability on initial teacher education programmes.

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Developing Student Teachers' PCK for Teaching Technology with a Sustainability Edge in Primary School

Anne-Marie Cederqvist, Halmstad University, anne-marie.cederqvist@hh.se
Per Högström, Halmstad University, per.hogstrom@hh.se

ABSTRACT

In Swedish primary schools, technology teaching may appear different depending on what educational setting the pupils meet. Many pupils experience the subject of technology as taking part in practical making-activities without recognizing the technological knowledge involved, and many teachers feel uncertain of what and how to teach technology, especially concerning sustainability. Thus, it is necessary to pinpoint these issues within teacher education. This paper presents the first iteration of a Design-Based Implementation Research (DBIR) study on a teaching module that provides student teachers with theoretical and practical knowledge in technology education. The purpose of the study is to capture and understand how student teachers transform acquired knowledge and skills into Pedagogical Content Knowledge (PCK) for teaching technology in primary school. Special attention is on how student teachers evolve relations between technology education and sustainable development. The study is designed and implemented in line with DBIR based on principles of collaboration and has strong connections between practice and theory (Fishman & Penuel, 2018). The participating researchers, also the teacher educators, have together with teachers at a municipal technological resource facility jointly identified underlying premises such as policy document statements; topics and content of value for all participants; potential participating schools; and reviews of previous research. The study includes 12 student teachers enrolled in a science and technology course. Data is collected in several steps including student teachers' written individual reflections, their project assignments, their lesson plans, and focus group interviews. Based on qualitative content analysis, components of PCK are traced to elucidate the transformation of student teachers' PCK for teaching technology with a sustainability edge. The results contribute to knowledge of what efforts, such as teaching module design features and connections to sustainability, should be made to develop student teachers' PCK for teaching technology in primary school.

Keywords: Design-Based Implementation Research, Pedagogical Content Knowledge, Sustainable-Development, Teacher Education, Technology Education

6. INTRODUCTION

Technology education has an important purpose to fulfill when it comes to developing pupils' understanding of technology in everyday life, which also involves making pupils aware of sustainability issues. However, technology teaching in primary school may look very different depending on what classroom pupils enter. Many teachers are uncertain about what technological knowledge the content in the curriculum represents and what approaches characterize the subject. This has led to pupils taking part in many practical 'making' activities without understanding the technological knowledge involved (Norström, 2014; The Swedish School Inspectorate [Skolinspektionen], 2014). Furthermore, teachers feel unprepared when it comes to teaching about sustainable development (SD) (Pegalajar-Palomino et al., 2021). An important step to prevent these problems is to provide student teachers with both theoretical and practical knowledge of technology and help them transform it into Pedagogical Content Knowledge (PCK) for teaching technology. Further, education for sustainability needs to be integrated more explicitly (Pavlova, 2013; Pegalajar-Palomino et al., 2021). To take a grip on these issues we have jointly generated a collaboration between teacher educators and KomTek which is a municipal technology school that offers in-service teachers practical technology activities. The purpose is to develop a teaching module in teacher education that develops student teachers' PCK for teaching technology. This study aims to capture and understand how student teachers transform acquired knowledge and skills into Pedagogical Content Knowledge (PCK) with special attention to sustainable development.

7. LITERATURE REVIEW

7.1. Technology Education and the future technology teachers

Swedish compulsory education and teacher education are interrelated, pupils are to be educated toward curriculum goals, and teachers must be prepared by teacher education to be the facilitators of their pupils to achieve curriculum goals (Åstrand, 2023). However, a report by the Swedish School Inspectorate (2014) on technology in primary schools showed several shortcomings. Teachers feel unsure of what the content of the curriculum represents in terms of technological knowledge, as well as what approaches characterize the subject of technology. Norström (2014) suggests that it is important that technology teachers can interpret what content in the curriculum represents to be able to present high-quality technology education, as well as providing an equivalent assessment and grading of pupils (Jones et al., 2013).

Practical activities are an important element in technology education. However, teaching technology has become more defined by its practical activities in the classroom than its purpose and learning goals (Fahrman et al., 2020). As a result, there is a risk that pupils' learning of technology is limited (The Swedish School Inspectorate, 2014), as well as it becomes difficult to assess pupils' learning (Fahrman et al., 2020). The abovementioned highlights the importance of preparing future teachers with knowledge that characterizes the subject of technology. Knowledge in this sense implies conceptual knowledge, i.e., understanding technological concepts, and procedural knowledge, i.e., being able to practically take on technological tasks (McCormick, 1997). When teaching technology, teachers must be aware of, and address conceptual and procedural knowledge, as well as critical knowledge concerning the consequences of technology on our lives, on society, and the environment (de Vries, 2016). Therefore, it is of utmost importance for teacher education to prepare future technology teachers with content knowledge that includes conceptual and procedural knowledge, and knowledge of SD, as well as pedagogical competencies for teaching technology.

7.2. Transformations in technology and sustainability education

Education for sustainable development (ESD) is highly relevant to ensure that all learners can be able to contribute to achieving the global sustainable development goals (SDG). However, efforts made so far have not been sufficient (Pegalajar-Palomino, et al., 2021; UNESCO, 2018). Teachers are less prepared, i.e., lack the professional competencies needed, to teach about sustainability and sustainable ways of living (Pegalajar-Palomino, et al., 2021). Thus, key competencies including knowledge, skills ('what'), values, beliefs, and worldviews ('why') must be included as well as pedagogical competencies ('how') in teacher preparation. Pavlova (2013) argue that transformations of teaching within science and technology education are crucial. To embrace SD, it must be relevant for self or community, include practical solutions, and involve value-driven socio-scientific decision-making.

Since individual agency are crucial for SD, inner qualities and capacities for transformation have gained attention (O'Brien & Sygna, 2013; Wamsler, 2020; Wamsler et al., 2021). Inner qualities relate to the 'why' in ESD and the transformation of personal beliefs, values, and worldviews is considered the most powerful source to transform actual outcomes in practice (O'Brien & Sygna, 2013). However, the lack of individual agency is consistent, mainly due to structural constraints (Wamsler et al., 2021). A transformation of learners' mindset can be achieved in different ways, both as an end and means. In such processes, inner qualities must be addressed by giving opportunities for learners to include self-awareness, empathy, sense-making, sense of purpose, and sense of empowerment. In this study, we approach SD in line with research on ESD (e.g., Pegalajar-Palomino, et al., 2021), with particular attention to inner qualities and capacities for transformation (e.g., O'Brien & Sygna, 2013).

7.3. Pedagogical Content Knowledge (PCK)

PCK is widely used in educational research to examine the professional knowledge of teachers, as well as to examine student teachers' development of this professional knowledge. Over the years, researchers have taken a departure from Shulman's definition of PCK (1986) and developed new models of PCK. One of these, commonly used to analyse and capture teachers' PCK, is the refined consensus model (RCM). The model represents the content-specific nature of PCK when teachers engage in pedagogical reasoning during their teaching. In these situations, practical teaching activities are recognized as opportunities in which teachers' professional knowledge can be both manifested and generated (Carlson et al. 2019). The RCM makes three areas of PCK explicit (collective PCK, personal PCK, enacted PCK) as well as representing their relationships and how knowledge components of PCK flow between them. In this study, we take departure in the knowledge components of PCK in the RCM to capture and understand how student teachers transform acquired knowledge and skills into PCK when planning, enacting, and reflecting on teaching technology for primary school pupils.

7.4. Design-Based Implementation Research and Design Principles

In DBIR additional stakeholders other than the researchers are invited to the design of the research project. DBIR strives to create the conditions for studying processes that occur when stakeholders at different levels interact with a relatively clear objective of what to implement (Fishman & Penuel, 2018). In this study, we recognize that the benefits of the design process also benefit the implementation in a broader perspective. The process includes identifying design principles (DPs) that support the identification of outcomes through the course of a study (McKenney & Reeves, 2018). Within our study, the identified DPs are informed by technology education and ESD literature. In short, these are as follows:

- DP1: Basing the study within DBIR as a methodology (Fishman & Penuel, 2018)
- DP2: Supporting the establishment of iterative cooperation between stakeholders (Fishman & Penuel, 2018)
- DP3: Incorporating interior dimensions and personal values as a guide for pedagogical considerations about SD (Holbrook, 2009; Pavlova, 2013; Wamsler et al., 2021)
- DP4: Supporting transformed learning opportunities informed by PCK (Carlson et al. 2019)
- DP5: Integrating conceptual and procedural knowledge within the teaching activities (Norström, 2014; Pavlova, 2013)

8. METHOD

In this study, we present the first iteration of a teaching module in teacher education. Informed by DP1, the framework is founded upon a qualitative DBIR research methodology. This is supported by the cooperation between researchers as teacher educators and teachers at KomTek (DP2), the teaching and the assignments oriented towards teaching with pedagogical considerations about SD, the development of professional knowledge and the integration of both conceptual and practical aspects of technology teaching (DP3, DP4, and DP5).

8.1. The Educational Context and the Teaching Module Design

This study is based on a course module within a Science and Technology course of 30 credits. The student teachers enrolled in the course are preparing to become teachers in primary school, grades 4–6. In total, the course module includes 12 sessions which are divided into two theoretical blocks, one practical block, and one synthesising block (see Table 1). During the synthesising block, the student teachers are planning in groups and enact technology teaching using knowledge captured from the previous blocks.

Table 7.
Applying a DBIR framework for the teaching module in teacher education (DP3, DP4, and DP5).

Block	Content	Activities
Block 1 Theoretical Session 1–4[a]	Epistemology of technology History of technology Design and technological documentation Construction techniques, strength and durability theory, and materials	Literature seminars Group work Workshops
Block 2 Practical Session 5–8[b]	KomTek: Mechanics and Digital Models Everyday mechanics Programming	Practical technology workshops
Block 3 Theoretical Session 9[c]	Technology, human, society, and technological systems	Discussion seminars on SD, safety, ethical considerations Workshop with a debate on SD/technology, and discussions on ethical dilemmas
Block 4 Synthesising Session 10–12	Plan and teaching technology	Planning lesson: Mechanics TinkerCad Programming Electronics Lesson plan revision[d]. Perform lesson with pupils[e].

Note: [a] = 180 min each; [b] = 180 minutes each; [c] = 180 min; [d] = 180 min each; [e] = 240 min for each group, 90 min lesson with pupils.

8.2. Data collection and Analysis

The study includes two researchers as teacher educators, two KomTek teachers, and 12 student teachers. In addition, eight municipal schoolteachers, 42 4th-grade pupils, and 38 5th-grade pupils provided authenticity to the student teachers' lessons.

Data was collected in several phases of the module. Student teachers' individual written reflections on technology education and SD were captured before and after the teaching module. Further, the student teachers' lesson plans were collected. Semi-structured interviews were conducted after performed lessons. Furthermore, data were collected from the individual project assignment.

The framework for analysing the qualitative data was informed by content analysis (Selvi, 2020). Coding was carried out deductively using five PCK components derived from the research literature: Knowledge of content (conceptual knowledge, procedural knowledge, knowledge of SD); Knowledge of curriculum; Knowledge of instructional strategies; Knowledge of students; Knowledge of assessment (see Carlsson et al., 2019; Magnusson et al., 1999), and also codes for inner qualities and capacities for transformation were used (e.g., empathy, courage, relating, cooperating, critical thinking). Inner transformation involves changes in people's consciousness, and as used in this study, it describes changes in student teachers' attitudes and related cognitive or emotional abilities (see Wamsler, 2020; Wamsler et al., 2021). To present the findings, we created vignettes as transformative accounts. However, in this paper we have chosen to present the findings based on one student teacher (Kim) who represents the inherent complexity of developing PCK for teaching technology in primary schools during the semester. Kim can be seen as an exemplifying case for the larger group of student teachers who participated in the same course.

9. RESULTS

The results show a transformative account from the student teacher Kim, in which we have outlined a course of excerpts from various data. At the beginning of the course, Kim's individual written reflections on previous experiences of technology education and SD were collected.

> ...it was often that, as I remember the technology lessons, as the teacher might not dare to try so many new things..., we were building bridges and then we built bridges every year…

In the following excerpt, Kim presents what is important to consider when planning and teaching technology integrated with SD.

> […] You must have a good understanding of technology development concerning SD […]. You should also consider the pupils you meet by observing their interests and pre-understanding to be able to see what they need to develop […]

This initial part indicates need for knowledge e.g., ***knowledge of content*** concerning both conceptual and procedural knowledge, and about SD. Kim expresses that to implement good teaching in technology, you need to integrate knowledge of both technology and SD. Her previous experience in technology education is described as practical, limited to activities such as building bridges. However, Kim shows PCK components such as ***knowledge of instructional strategies*** and ***knowledge of students*** since she describes the importance of considering pupil's pre-understandings and how to use this when planning teaching.

The student teachers plan lessons that they enact with pupils at the KomTek facility. Kim's group presents a lesson where the pupils learn to produce digital models of chess-pieces in Tinker-Cad and printing it on a 3D-printer. The waste hierarchy (Lansink's ladder) is introduced to the pupils. In the group interview, Kim discusses the chess-set activity.

> I think that it feels more real when you have activities like this with the chess-game as it is a situation that they can recognize from their everyday life […].

Further, Kim discusses the way SD is connected to technology education and how a new way of thinking has occurred.

> […] I don't remember that we have encountered something like this where you must think about the materials you use or how to construct things, or think sustainably, it was new for me. [...] now it just feels obvious that it should be fitted together.

In the group interview Kim also expresses her achieved knowledge about plastic materials and recycling of plastics, which she uses in the lesson at KomTek.

> […] I had to change my thoughts a lot concerning that we think we take care of plastics very well and that we can recycle it. But then we saw that it is such a small percentage that we can take care of …

In this part, we have captured components of PCK such as ***knowledge of content*** concerning procedural and conceptual knowledge, and SD. Kim mentions especially knowledge of materials such as plastic and how this is necessary to integrate with sustainability when constructing technological solutions. She also mentions the use of practical activities that pupils relate to. This indicates that her ***knowledge of instructional strategies*** has been further developed.

In the individual project assignment, where the student teachers are expected to reflect on the lesson at KomTek, Kim elaborates on the lesson.

> The task invites discussions and reflection regarding the choice of materials, waste, and the structure of the construction with a focus on stability and durability as constructing with 3D printers makes it possible to influence these points. […] the pupils also need to develop knowledge of documentation such as sketches and digital models [...] During the work, the teacher invites to discussions about the material, structure, strength of the pieces, and the pros and cons of the production method concerning SD. […] Assessment will be made on pupils' reports and documentation in the form of sketches, digital models in TinkerCad, and finished products. All parts are assessed according to the grading criteria for the technology curriculum.

Kim's teaching idea includes several indicators of developed PCK. The PCK component ***knowledge of content*** (conceptual knowledge) is captured from her choice of contents such as the structure of the construction with a focus on stability and durability. Further, procedural knowledge is captured such as documentation in terms of sketches, digital models, and reports, and how to construct a model with a 3D printer. Also, ***knowledge of instructional strategies*** has developed. She is presenting lessons that integrate practical and theoretical sessions where pupils reflect and discuss the content and processes concerning SD. Further, she presents ways to assess pupils' learning in relation to grading criteria in the technology curriculum. This indicates that Kim also developed PCK components such as ***knowledge of curriculum*** and ***knowledge of assessment***.

After the teaching module has been carried out, Kim's individual written reflections were collected. The except below shows her new experiences and views of technology education and SD

> To be able to take a stand on issues that concern technology in relation to SD, it is important to first develop pupils' understanding of the technology that the questions concern and what its pros and cons are in relation to society, the environment, and humans.

The excerpt indicates that the PCK components' ***knowledge of content*** and ***knowledge of instructional strategies*** are present. Kim suggests that to learn and understand technology in relation to SD and being able to make well-informed decisions, it is necessary to first develop an understanding of the technology itself. Below Kim reflects on the connection between technology and SD.

> […] SD implies using and developing technology without jeopardizing the living conditions for future generations. […] I believe that the two concepts should always be connected as technology can have very negative consequences if we do not have SD in mind when we create, use, and develop the technology. […]

The vignette also shows how Kim's inner qualities are expressed. Regarding her view on the relationship between technology and SD, a transformation towards a more ***empathetic*** reasoning is present. Also, she is ***relating*** to pupils' needs for authenticity and making informed decisions in complex SD issues. During the enactment of the teaching module more arguments showing ***critical thinking*** are used.

10. DISCUSSION AND IMPLICATIONS

The results indicate two design principles in the first iteration of the teaching module that needs further attention. The first one is DP3 which is to incorporate the personal values of SD as a guide for pedagogical considerations about SD. Although the student teachers have transformed on a personal level regarding their view of sustainability in relation to technology, there are still difficulties in integrating activities that may help student teachers promote the pupils' understanding. This is evidently a persistent problem (Holbrook, 2009; Pavlova, 2013; Wamsler et al., 2021). In the first iteration, we included possibilities for student teachers to reflect on beliefs, values, and worldviews, in line with O'Brien and Sygna (2013) and Wamsler et al. (2021). In our data, several accounts support a transformation of the student teachers' mindsets, for example, increased statements that included empathy for people and nature. But still, inner qualities and capacities need additional attention to help the students address interior dimensions, which is crucial for the development of individual agency (Wamsler, 2020). Therefore, we choose to introduce lectures and inner qualities labs as off-schedule opportunities in a rearrangement of the teaching module (see Table 2).

Furthermore, there is still incoherence between the content presented and the practical activities. That is, there is a need for focus on DP5, to integrate conceptual and procedural knowledge. According to Norström (2014) and Pavlova (2013), this could be benefited from repeated practice. The re-design implies that synthesising, hence integrating, appears twice in the teaching module (Table 2). Also present in our second iteration, KomTek as cooperating stakeholders are rearranging their practical sessions informed by theoretical sessions. Such joint efforts to enhance outcomes should be beneficial (Fishman & Penuel, 2018).

Table 2.
The re-designed DBIR framework for the teaching module in teacher education

Block	Content	Activities (on schedule)	Activities (off schedule)
Block 1 Theoretical Session 1-5[a], and Inner Qualities Session 1-4[b]	Epistemology of technology History of technology Design and technological documentation Construction techniques, strength and durability theory, and materials Technology, human, society, and technological systems	Literature seminars Group work Workshops Discussion seminars on SD, safety, ethical considerations Workshop with a debate on SD/technology, and discussions on ethical dilemmas	Inner Qualities Lectures: Presence and Learning Mindset Reflective listening Sense-making Complexity awareness Inner Qualities labs: Meditation Mirroring Conscious story of life Sense of purpose
Block 2 Synthesising Session 6[c]	Introduction to planning and teaching technology	Planning lesson: Mechanics TinkerCad Programming Electronics	
Block 3 Practical Session 7-9[d]	KomTek: Mechanics and Digital Models Everyday mechanics Programming	Practical technology workshops with theoretical base from Block 1	
Block 4 Synthesising Session 10-11	Plan and teach technology	Lesson plan revision[e]. Perform lesson with pupils[f].	

Note: [a] = 180 min each; [b] = lectures, 15 min each, labs, 30 min each; [c] = 180 min; [d] = 180 min each; [e] = 180 min each; [f] = 240 min for each group, 90 min lesson with pupils.

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Insights from the Implementation of the Course “Development of an Interdisciplinary STEM Project Via PBL Approach” in an 'Integrative STEM Education' MEd Program

Osnat Dagan, Beit Berl College, osnat.dagan@beitberl.ac.il
Noa Ragonis, Beit Berl College
Daphne Goldman, Beit Berl College

ABSTRACT

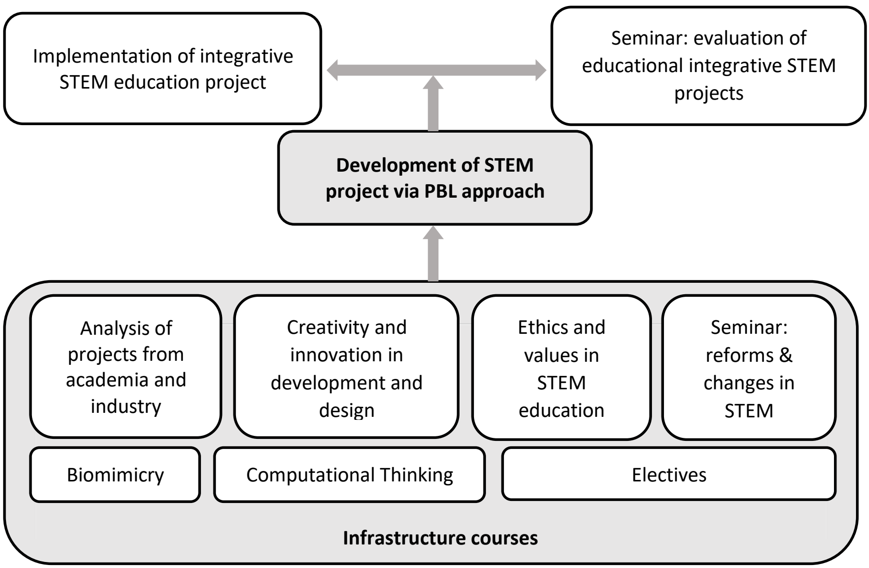
The paper explores the implementation of the problem-based learning (PBL) pedagogical approach in an academic course titled "Development of an Interdisciplinary STEM Project via PBL Approach" This course is one of the key courses in the master's in education (M.Ed.) degree on integrative Science, Technology, Engineering, and Mathematics (STEM) education developed at Beit Berl College, Israel. The M.Ed. program trains educators to design and implement interdisciplinary STEM curricula in schools and other educational settings. The course objective is to provide students with hands-on experience in the development of a STEM project. It is a 6 ECTS credits course extending two semesters. In this course, the students work in a multidisciplinary team and identify a problem relevant to society for which they develop a solution as a product. The teams plan their path to solving the problem, investigate and locate information to support the process, plan their timetable, and determine the criteria for assessing the product and their own PBL-based learning process. The project needs to include a response to Sustainable Development challenges. The course is co-taught by three lecturers from different disciplines: environmental sciences, computer science, and technology. Each lecturer contributes to the learning process from her specific field of knowledge, different educational backgrounds, and accumulated academic experience. This paper analyses, via the students, the course implementation through the lens of seven PBL essential attributes to evaluate the learning process, address challenges and proposes recommendation for similar courses.

Keywords: STEM education, Problem solving, PBL, Teacher professional development, Design thinking; student perspectives.

1. INTRODUCTION

This paper examines the implementation of the course titled 'Development of an Interdisciplinary STEM Project via PBL Approach' (from here on 'the course') conducted within the M.Ed. program 'Integrative STEM Education'. This unique program aims to (1) enhance students' knowledge and comprehension of STEM fields, and develop their pedagogical content knowledge (PCK), and technology PCK (TPACK) for teaching STEM, and (2) equip the students with the competencies to lead and manage interdisciplinary STEM learning approaches in educational institutions (Ragonis, Goldman & Dagan, 2023; Dagan, Ragonis, Goldman & Wagner, 2019). Additionally, the program encourages students to observe their teaching as a fruitful research field. Figure 1 presents the logical structure of the M.Ed. program, in which 'the course' ' holds a central role. The program is unique in that all the courses and interconnections among them are designed to scaffold the development of knowledge and skills from an interdisciplinary perspective. Emphasis is placed on two key aspects: the engineering design process and the PBL approach. Additionally, the program underscores ethical considerations in STEM education, the crucial role of Sustainable Development in the contemporary world, and the perspective of teacher-as-researcher (Guha, 2021). Building on these foundations, the program includes two core project-based courses: 'Development of STEM Projects via PBL Approach' and 'Implementation of integrative STEM education project' complemented by the empirical seminar 'Evaluating Educational Integrative STEM Projects'. The program's pedagogical principles emphasise constructivism, constructionism, co-teaching, learning by need, and PBL.

Figure1.
The logical structure of the M.Ed. program



The study presented herein investigates the application of PBL in 'the course' as reflected in the students' experience. In particular, to investigate how students experience PBL as a process of learning and how does this reflect on the course goals?

2. LITERATURE REVIEW

2.1. Science Technology Engineering and Mathematics (STEM)

The term STEM is widely used in education to promote the integration of science, technology, engineering, and mathematics disciplines, reflecting their interconnectedness in the real world. While STEM is often understood as science- or mathematics-focused, the inclusion of technology and engineering is less prevalent. Dugger (2010) outlined three structures for STEM education: a) teaching each STEM discipline separately with limited integration, b) giving more emphasis to certain disciplines (typically science and math), and c) integrating one STEM discipline into the other three. It is increasingly recognized that current learning processes in schools and higher education do not adequately address the integration of STEM disciplines. In response, various curricula and initiatives have emerged (Bybee, 2013; Cagle, Caldwell, & Garcia, 2018; Sanders & Wells, 2006). The primary goal is to prepare students for a complex and unpredictable world, in which interdisciplinary professions and teamwork are essential for problem-solving, innovation, and entrepreneurship. Effective integrative STEM education enhances students' holistic understanding of the world and how things work, their technological literacy, and their capacity for innovation and problem-solving (Bybee, 2010; 2013). Addressing these challenges guides the curriculum of the M.Ed. program and provides the conceptual foundations of the course explored in this study.

2.2. Project Based Learning

PBL is a process that takes place over time, extending beyond the limits of regular lessons. It enables students to be active in learning by doing, to be creative and innovative, and to work independently or in teams while designing solutions to real-life, ill-defined problems. The PBL approach involves exploring, creating, and constructing (Dagan, 2023). This learning method necessitates the learners' use of critical, analytical, and synthetic thinking, evaluation, and reflection on their problem-solving processes (Capraro & Slough, 2013).

STEM literacy that is built on PBL is important for all students and is identified as a "Meta Discipline" (Zollman, 2012). Learning via the PBL method provides authentic content and context-related experiences that are crucial to the learner and are used to support meaningful and effective learning in STEM (Capraro, Capraro, & Morgan, 2013). Engineering design is a central pillar in STEM PBL; the learners use their knowledge of science, technology, and math to solve real-life, open-ended, and ill-defined problems (Capraro & Slough, 2013).

Six PBL characteristics were defined by Dagan (2023):

(xiv) *The problem*. Should be "wicked," ill-defined, open-ended, relevant to real-life situations including the learner's world, enable conceptual understanding, include various subjects, have different ways to be solved, and cultivate meaningful competence.

(xv) *The process*. The learners solve the problem in an iterative process using design tools (Mioduser, 1998) and design skills (Klappwijk, 2018), as shown in Figures 2 and 3.

Figure 2.
Design tools (Mioduser, 1998)

(xvi)

Figure 3.
Design skills (Klapwijk, 2018)

(xvii)

(xviii) *The product*. The process culminates with a tangible product that meets the defined problem's needs and constraints.

(xix) *The teachers' role*. Is to guide, assist, support, and mediate the students' learning processes by managing the learning environments and the process and setting the general timeline.

(xx) *The learners' roles*. Are to work collaboratively in teams, to be independent, and to construct their own knowledge and skills. Learners are responsible for the learning process, timetable, and assessment.

(xxi) *Assessment*. The assessment criteria and their weight are planned and used by the learners.

These PBL characteristics provide the basis for the course's method and for the students' individual constructed reflections, which serve this study.

3. METHODOLOGY

3.1. Description of the course

The course aims to provide students with practical experience in developing a STEM project within the college environment. The course extends two semesters and models the integrative approach via team teaching of three lecturers from different disciplinary backgrounds: computer science, biology and environmental education, and technology education. The course's main aim is to enable actual experience in the long-term process of developing a valuable STEM project leading to product development. The project is carried out in multidisciplinary teams in which each team member has a different disciplinary background. The students are expected to contribute their knowledge and learn from their teammates to jointly achieve the development process via the design process. We consider it crucial that students experience such a significant process themselves towards their ability to apply such learning processes, that involve challenges, frustrations, and successes, in their respective educational frameworks.

Learning outcomes are that at the end of the course, the student will be able to: 1) Address problem-solving in a PBL approach, from defining the problem to presenting a solution and evaluating it; 2) Identify analogies and connections among the involved fields of knowledge; 3) Define criteria for evaluating suggested solutions and apply them; 4) Conduct thorough research to establish a foundational understanding for addressing the problem and its potential solutions and present this with clarity and focus; and 5) Document the PBL process systematically. Moreover, we addressed outcomes related to skills - the ability to: 1) Work in Teams; 2) Define group work practices; 3) Give and receive feedback; 4) Deal with constraints; 5) Manage a schedule; 6) Deal with disagreements; 7) Reflect individual and teamwork.

The main task of the course as defined for the students is: to define a problem whose solution is a product that requires a combination of STEM fields, takes into consideration sustainability issues, and responds to a societal necessity. The development process is based on the engineering design process and is conducted via the PBL process. To develop the students' understanding of sustainability, two introductory lectures are given. Students collaborate in teams, contributing their diverse disciplinary knowledge and expertise to the project. The Design process and the PBL principles and skills were taught and applied in previous courses and are revisited at the onset of the course. The course lecturers acted as supervisors and consultants, and additional experts (e.g., electrical engineer, industrial designer, chemist) provided advice according to the student's needs. The process commenced with the students selecting the problem and writing a design brief utilizing prior knowledge and skills. The iterative Design models they previously learned, such as Mioduser (1998) and Klapwijk (2018), were employed. Students had the autonomy to choose their design path, and to manage their timetable. Moreover, they were requested to determine their own assessment criteria, relating to the entire development process and the product, and to follow it. Together with the construction of the product, the course outcomes included a portfolio documenting the developing process. This included the research, constraints, inputs from intermediate presentations of experts and how they influence the process, a sketch model of their product and a tangible product to be presented for feedback and evaluation to peers and other guests, inspection of the compatibility of the product to its defined requirements, and assessment tools. The students also submit an individual constructed reflection.

The first cohort of students chose to address a human challenge arising from climate change - the need to lower the temperature of the immediate environment surrounding an individual's body when outdoors. For this purpose, they developed an "Umbrecoola", which is a portable umbrella with a cooling system.

3.2. Method

The research data are the individually constructed reflection documents that the first cohort of students (four) completed at the end of the course. The reflection protocol related to the seven PBL characteristics: defining the problem, the design process of creating a solution to the problem, developing assessment criteria, establishing a timeline, and managing it, applying theory to practice beyond a discipline (here, the interdisciplinary approach), teamwork, the student's responsibility for the process while the lecturers serve mainly as facilitators. The students reflected on each of these criteria addressing three questions: 1) What were the challenges you confronted? 2) How did you act to meet these challenges? and 3) What did you learn from this? Additional questions mainly about what they take from the course experience to their future work as teachers are not addressed in this paper.

Content analysis was conducted on the students' responses.

4. FINDINGS

The findings offer a comprehensive overview of the students' perspectives. The organization is upon seven PBL aspects, in each answer to the three questions posed to the students are presented. The students' initials, indicating their mentioned aspects, are provided in parentheses at the end of the claims.

4.1.1. Aspect 1: Finding a topic and identifying the problem.

- *Students' Challenges*. The main challenge raised by students focused on finding an unsolved problem that aligns with the project requirements. "… a problem that motivates us, aligns with our research and technology capabilities, and considers sustainability…" (ES). The iterative process of continuous refinement of the accuracy of the problem throughout the entire process was also challenging for them (DS, YN).
- *Coping with the challenges throughout the process*. Students reported that they: (1) conducted brainstorming sessions (YN) and, (2) employed democratic decision-making through open dialogue (TS, DS). Moreover, in the process, they narrowed the scope of the problem and requested assistance from relevant faculty and other consultants (ES).
- What did you learn personally? The students testified that they learned to choose authentic problems and to apply them in their own teaching (YN, ES); that consensus in decision-making is vital (DS); and that their self-efficacy was strengthened despite the difficulties (TS).

4.1.2. Aspect 2: The problem-solving process

- *Students' Challenges.* Students faced several challenges: From their perspective, the research phase did not transpire at the appropriate time in the design process (TS, YN, DS, ES) the solution they selected for the problem was technologically ambitious and with high technical constraints (DS); time limits (ES); the need to choose a solution iteratively under these constraints caused frustration (DS).

- *Coping with the challenges throughout the process*. The students conducted counseling sessions with experts, which led to lowering excessive expectations (ES), focusing on the product, and using a categorization rubric to select the appropriate solution under the given constraints (TS, YN, DS).
- *What did you learn personally?* Students learned that: the non-linear, spiral, iterative approach is effective (TS, ES); the research should be conducted according to needs that arise during the process (YN); it is important to conduct feasibility testing before detailed planning (ES). Furthermore, they acknowledged the importance of constantly monitoring their own progress (DS).

4.1.3. Aspect 3: Formulating and developing assessment criteria

- *Students' Challenges.* Students found the need to develop their own assessment criteria challenging, particularly in relation to allocating points for each criterion while balancing awareness, professionalism, and fairness (DS, YN). They found it difficult to find the balance among the components when efforts are invested across all aspects of the process (TS, YN, DS, ES).
- *Coping with the challenges throughout the process.* They collaborated and shared ideas to overcome controversies, and revised the indicators based on the faculty's feedback.
- *What did you learn personally?* The students stated that the necessity of a clear formative assessment tool for self-management became clear to them, and that starting by defining metrics eases the process (DS). They also felt that involving students in the process boosts motivation and ownership (TS, ES, YN).

4.1.4. Aspect 4: Determining and managing a schedule.

- *Students' Challenges:* To create and follow a project schedule within the time limits despite deviations that occur in the process (ES, YN).
- *Coping with the challenges throughout the process*. They minimized deviations (TS), narrowed the problem to meet the deadlines (DS), and maintained full team cooperation - planning together and seeking full agreement (ES, TS).
- *What did you learn personally?* Students learned that time management is vital in PBL, that it is required to use accessible tools to acquire and practice this skill, and that changes are an inevitable part of project management (TS, DS, YN, ES).

4.1.5. Aspect 5: Expressing the integrative disciplines in STEM

- *Students' Challenges:* Lack of STEM disciplinary knowledge that was necessary towards the product development (DS). They also stated that the main challenge was aligning problems with sustainability (TS).
- *Coping with the challenges throughout the process*: The students stated that consulting with the lecturers and experts from various STEM subjects supported their inquiry into the different fields and helped in acquiring the necessary knowledge (ES).
- *What did you learn personally?* Students learned that the interactions with cross-disciplinary experts directed them to relevant STEM information (ES, YN), relevant indicators, and hence supported a better and more applicable process (DS, TS).

4.1.6. Aspect 6: Teamwork

- *Students' Challenges*: To utilize the strengths of each team member (YN); accommodate differences in working styles (DS); synchronize shared time (TS); divide tasks; and provide mutual support to "our enjoyable teamwork" (ES).
- *Coping with the challenges throughout the process*: "…Like a crane flock, everyone in the team took the lead when they could and stepped away from the arrowhead when they got tired." (TS). The students mentioned that they divided roles among themselves evenly and decided collaboratively on the subsequent steps, holding scheduled summary meetings (ES, DS, YN).
- *What did you learn personally?* Students stated that they learned to release control and trust others (YN), to appreciate diverse perspectives (DS, ES), and that all these components boost their motivation, mutual support, and growth (TS).

4.1.7. Aspect 7: Transferring the responsibility for learning to students.

- *Students' Challenges*: Releasing control; trusting others (YN); enabling diverse perspectives (DS, TS); and receiving seemingly conflicting messages from the faculty (ES).
- *Coping with the challenges throughout the process:* They distributed responsibilities based on each teammate's expertise (YN, TS); asked questions and consulted with the faculty (ES). They also stated: group work, maturity, and experience (TS, DS, YN, ES).
- *What did you learn personally?* Students learned that the space needed for embracing mistakes requires a non-judgmental teaching style (ES); transferring learning responsibility to learners involves the need to monitor it (TS); excessive freedom can create challenges and a defined framework is necessary (DS, YN).

5. DISCUSSION

The discussion centers on students' experiences with PBL as a learning process and its reflection on the course objectives. The content analysis of the students' responses reveals that through their active engagement in the process of PBL, they were able to identify the PBL characteristics and comprehend their significance to the learning process. They overcame challenges they encountered by building on the power of teamwork, self-regulation such as narrowing the range of the problem to be solved and seeking professional assistance from the faculty and additional experts. These strategies reflect 21-century skills central in contemporary [STEM] education that these teachers are expected to cultivate in their students.

The students experienced all six PBL principles (Dagan, 2023). A specific challenge they experienced was the difficulty in identifying a problem that motivates them but is also suited to their knowledge and capabilities. This led to their insight into the importance of focusing on a problem that can be solved within the allocated timeframe. They engaged in iterative problem-solving through design, utilizing two previously learned design tools (Mioduser, 1998; Klapwijk, 2018). Despite their prior experience in design, and their understanding of the iterative nature of the process, when conducted as a whole process, they found it challenging and frustrating. An important attribute of PBL is the learners' responsibility regarding assessment. The students comprehended the importance of taking on the role of developing the assessment criteria for their process and product, since it offers insights into the specific efforts and skills required for each component and helps determine their relative importance. Through planning the timetable of the project, they understood its importance for the learning process, but also that flexibility is needed, since changes are inherent to the PBL process. The students encountered gaps in their STEM knowledge related to the selected problem but viewed this as an opportunity for new learning. This corresponds with a central principle of PBL- active construction of knowledge through the learners' participation in a real-world problem (Blumenfeld, & Krijcik, 2005). They built on teamwork: they divided roles, put trust in their teammates and embraced the diversity of perspectives contributed by the different professional background of each member as well as their different approach to looking at the problem-at-hand. Importantly, these students acknowledged the need to be responsible for their project as the main PBL characteristic (Dagan, 2023), and viewed it as a crucial element.

The most difficult aspects of PBL encountered by these students were: 1) defining a problem such that it will be interesting to solve, embodies a feasible multi-disciplinary scope, and involves environmental considerations; 2) the iterative method which often creates frustration; 3) the positioning of the inquiry component in the process that was determined by the lecturers and did not fit into their design rhythm; 4) the need to listen to others' opinions; and 5) the need to decide on their own assessment criteria. All the students expressed how they were able to connect various aspects of the overall process and acknowledged that it provided valuable insights into teaching and learning within a STEM PBL environment. They expressed a desire to apply this newfound knowledge in their respective educational fields.

Analysis of the students' responses supports that in the process of developing the STEM project, the course met all its goals. Their responses reflect the development of a deep understanding of the principles of PBL. Importantly, their experience of the different challenges associated with the different aspects of the PBL learning process developed their awareness of how to work, as teachers, with their students. The following quotes nicely reflect this:

> "It opened a new way for me as a teacher to transfer learning responsibility to the students and be a facilitator who directs and monitors the process of making." (YN);
>
> “It allows me as a teacher to know where the points of failure are, to know what should be more or less structured, how to assist learners in the process, and above all, how to really implement a PBL project in the best way for all partners in the process." (ES);
>
> “It mainly opens the mind and allows me to think and dream. I don't really know if it can be applied at this point.” (DS);
>
> "To understand that the main goal of the PBL process is to develop personal abilities along with empathy, which will increase the chances that he/she will grow up to be a person engaged in improving the world.” (TS).

The course effectively implements Dugger’s (2010) type C approach, integrating disciplines within the engineering design process for STEM content. Furthermore, the course effectively incorporates PBL as a learning approach, as demonstrated by the students' comprehension and application of the seven components of PBL (Dagan, 2023; Bybee, 2013). However, some components posed challenges, while others were easier to implement. A major goal of this M.Ed. program is to equip experienced teachers with the competencies to lead and manage interdisciplinary STEM learning in their respective educational institutions. The students' responses provide evidence that their experience in the PBL process, and specifically the challenges they encountered, developed their awareness of the changes they need to incorporate in their role as teachers. Sterling (2009), in his discourse on 'Sustainable education - Education in and for change' emphasizes the necessity of transformative, constructive, and participatory education and pinpoints differences between conservative, mainstream transmissive education and transformative education. The students' reflections indicate that the course presented herein succeeds in making this move from transmissive to transformative education. For example, the focus was not on faculty's teaching but rather on students' bottom-up learning. The students had local ownership of learning as opposed to the faculty's control. Learning was process-oriented. The students learned in a constructive as opposed to instructive manner. Together, these indicate that the presented course made the shift from a teacher-oriented to a learner-oriented approach, overcoming one of the rhetoric-reality gaps in contemporary education.

6. CONCLUSIONS AND IMPLICATIONS

Based on the findings of this case study adaptations to the course were made to deepen the methodological tools required for students. First semester: developing the foundations of PBL skills, capabilities, and knowledge such as: teamwork, assessment and how to assess PBL projects, planning a flexible schedule, and incorporating what they learned in previous courses. Second semester: conducting the engineering design process in teams to solve the defined problem, during which they implement the skills cultivated in earlier stages.

From a holistic point of view, we can conclude that the course successfully implemented a learner-oriented approach, emphasizing student-centered learning, local ownership of learning, and a constructive learning process. This shift aligns with the need for transformative, constructive, and participatory education in the realm of sustainability and STEM education. Moreover, the students expressed a desire to apply this newfound knowledge in their respective educational fields. The implementation of PBL in interdisciplinary STEM education aligns with the need to prepare students for a complex and unpredictable world, where interdisciplinary professions and teamwork are crucial for problem-solving and innovation. The shift from teacher-oriented transmissive education to learner-oriented transformative education reflects the importance of providing students with ownership of their learning process and the opportunity to engage in constructive and participatory education.

Further research is needed to explore and refine these aspects in greater depth. Suggested directions for ongoing research around this and other PBL-based courses in this M.Ed. program include exploring: (a) How the PBL approach influences students' critical thinking skills and problem-solving abilities in the context of interdisciplinary STEM education? (b) The long-term effects of PBL on students' motivation and engagement in STEM education? (c) How the iterative nature of PBL impact students' perseverance and resilience when faced with complex and open-ended problems? (d) What are the best practices for facilitating collaboration and teamwork among students in PBL projects, particularly in an interdisciplinary context? (e) How does the PBL approach promote interdisciplinary thinking? Such research questions can direct further studies into the effectiveness of PBL in interdisciplinary STEM education, leading to continuous improvement and refinement of the pedagogical approach.

The study of this course provides valuable insights for the professional STEM education community in terms of curriculum development, pedagogical strategies, and the integration of interdisciplinary approaches.

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Experiences in Pedagogy of Design: Research and Design Teachers Frame of Reference About the Concept of 'Model'

Snjezana de Haan -Topolscak, Delft University of Technology, s.dehaan@tudelft.nl
Pauline Vos-de Tombe, Delft University of Technology
Merle Ebskamp, Delft University of Technology

ABSTRACT

The core of the Dutch Technasium secondary school course Research and Design curriculum (R&D is in Dutch called Onderzoeken en Ontwerpen O&O) is to involve students in real-life design (or research) problems with a problem owner at a company or organisation. Students explore the nature of the design problem, establish a design brief, explore possible solutions and work out one option into a design, a prototype or a product depending on the level of complexity. Students work and learn in teams coached by Technasium teachers. Some secondary school teachers are qualified to teach at Technasium if they obtain a certificate from the Technasium foundation through a number of short training courses. They are originally teachers in various subjects like mathematics, physics, physical exercise, language and so on. The other part of the teachers have a teaching degree in R&D next to a degree in engineering. Thanks to different backgrounds the teachers offer a variety of angles and know-how in different fields of expertise needed during a R&D activities. Such a composition is enriching and STEM supporting at the level of knowledge transfer. It is clear that some R&D teachers have no design pre-knowledge. A pilot survey of R&D students and teachers on the concept of model within design activities unexpectedly showed similar doses of confusion about the concept of model among students and teachers. Therefore when asked to teach a concept of model in design related activities teachers provided a different definition of concept. Often a physically built scale model or prototype is the form of model they recognize in designing. The danger of such an approach is that the students obtain very different, incomplete or incorrect knowledge about the concept of model in relation to design. Therefore the set of values and norms within the group of Technasium teachers is needed, to establish a design related frame of reference.

Keywords; STEM, Subject Research and Design (R&D), Concept, Model, Pedagogy of Design

1. THIS IS A MODEL

The aim of the research was to investigate the conceptual understanding of the term 'model' among R&D teachers with very different subject backgrounds and students. The reason for this was, firstly, that during the execution process of research or design assignment, concept learning is a very important aspect of the R&D subject. The meaning technological concepts have in students' minds directly affect their learning in technology because these concepts form a framework from which to construct other concepts and base actions on (Jones, 1997). Secondly, a survey conducted among students in their final R&D year revealed that the students had various frames of references of the term 'model'. This implies that the development of effective teaching strategies for this topic in the curriculum is necessary.

The survey was designed to explore the diversity of interpretations of the term among the students. Next to the picture of the model (see figure 1) the same statement was placed "This a Model"; do you agree or disagree?

Figure 1.
Two model examples; mathematical formula and scaled car

After informally asking subject teachers of the R&D subject what they understood by the term 'model', these teachers also did not appear to have the same frame of reference, which may have led to different ideas about what constitutes a model. It appears from various conversations that there may be no agreement on how to use the term 'model' in high school education. Prof. Dr. Van Joolingen (2017) underlines that knowledge about models is essential to teach students to reason critically and to give them insight into the workings of science. Lijnse (2008) endorses this. He states that a lot of research has now been done that shows that both teachers (van Driel 1997) and students (Grosslight et al., 1991; Vollebregt, 1998) have all kinds of problems with models. He cites the statement of Schwarz & White (2005): "there is ample evidence that students may not understand the nature of models or the process of modelling even when they are engaged in creating and revising models". Teachers and students therefore have problems using models. How did that happen?

The term model alone has many definitions, the Cambridge Dictionary (2023) already lists ten. It is difficult to establish unambiguous definitions related to R&D. Furthermore, the teachers have different backgrounds within R&D, in the science subjects, which may entail a different view on the concept of a model. No clear agreement has been found within secondary education on how to define the concept of a model. The Technasium has also not provided a definition of the concept of a model within subject R&D. In secondary education, the term 'model' may be explained by individual subject teachers. However, the question is whether this also happens in interdisciplinary subjects such as R&D. As stated in the abstract, at the moment, all secondary school teachers are qualified to teach at Technasium if they obtain a certificate from the

Technasium foundation through a number of short training courses at Technasium Academie, (Technasium Academie 2023). Only difference is the field of teachers' activity known as first or second grade of secondary teaching. This means that the R&D teaching team is usually composed of many different teachers who have competence in different subjects.

Ensuring that teachers share a common understanding of key concepts, such as the 'model, is essential for delivering a consistent, effective, and high-quality education, particularly in interdisciplinary fields like R&D. It enables teachers to provide consistency in the curriculum through effective and coordinated instruction, thereby standardising the learning experience. Students benefit by receiving clear and unambiguous curriculum content and can apply learned concepts in interdisciplinary contexts.

2. MODEL WITHIN DESIGN EDUCATION

In order to contour the R&D frame of reference for the concept of 'model', the natural science, mathematics and R&D have been examined in advance for the meaning of the concept of model and classification of types of models. Natural science includes earth science, physics, chemistry, astronomy, and biology, while mathematics is considered one of the four core subjects taught in schools, alongside physics, chemistry, and biology.

In the literature, the term "model" is defined in various ways. Lijnse (2008), Schwarz & White (2005), and Hestenes (1987) all describe a model as a representation of reality with a goal and an alleged area of validity. They differ in their specifics, with Schwarz & White (2005) emphasising representation rules and reasoning structures, and Hestenes (1987) focusing on observable patterns in physical phenomena. In secondary education SLO (2020), a simplified definition is used, describing a model as a schematic representation of reality.

Although there are various definitions of the term model, no unequivocal meaning or definition has been found within the natural sciences, mathematics and R&D for the term “model”. The definition depends on the field of knowledge. A common definition is that a model is 'always a simplification of reality'. Reality is according to Cambridge dictionary (2023) the state of things as they are, rather than as they are imagined to be. Several scientists (Wegner, 2017; Bede, Dennis & Miller, 2016), including Lijnse (2008), argue that a model has a purpose. These goals are very different in nature and can be divided into different main groups. In the absence of a definition, Van Driel (1997, pp. 179-180) has provided a number of characteristics by which a model can be recognized in the natural sciences such as:

- A model is always a model of something, namely of an object of investigation. The object of research can be a system, but also a phenomenon, a process, a 'thing', or something that does not exist (anymore) (such as a dinosaur) or whose existence is uncertain (such as a black hole).
- A model is a tool for research into the object in question. It is used as such because the object itself is not accessible for direct examination.

- A model shows a number of similarities with the object of research. Thus, a statement about a certain model can be 'translated' into a hypothesis regarding that object. Testing such a hypothesis (if possible) leads to new knowledge about the object of research.
- A model differs from the object of research in that reductions are applied when drawing up a model (for example, by deliberately ignoring certain aspects of the object of research in the model), by scaling or in some other way. The pursuit of simplicity plays an important role in the development of models (Ockham's principle). Features 3 and 4 contradict each other.
- A model therefore has a built-in compromise character and the researcher has a certain freedom in choosing a model. The research question plays a role in that choice.
- A model is not derived directly from the object of study, such as a photograph or a measurement result. It contains elements that the object of investigation does not possess. Creativity therefore plays a role in the choice of a model.
- In the course of a study, a model may undergo an iterative development. The object of research is always studied in more detail.

Different classifications are possible to classify types of models within the natural sciences and mathematics. This classification can be made, for example, on the basis of the purpose of a model, a level of abstraction or, for example, on the basis of the subject. In architecture and industrial design, models are often defined and classified on the basis of the design process (Eger, 2010; Knol, 2007; Karssens & Otte 2018). Different types of models are used at different stages of the design process. Usually those models then go from coarse to fine with regard to simplification of reality or level of abstraction. Abstraction is the opposite of reality according to Cambridge dictionary (2023), abstraction is the situation in which the subject is very general and not based on a real situation.

It seems that there is no agreement on the use of the term 'model'. There is no clear and unambiguous definition and classification available. Therefore teachers and students have different ideas about the term 'model' (Lijnse, 2008). This makes it difficult to instruct students about a model's functions and purpose in the design process. Van Joolingen (2017) underlines that knowledge about models is essential to teach students to reason critically and to provide insight into the working of science.

3. DEVELOPING FRAME OF REFERENCE

To investigate the conceptual understanding of the term 'model' among R&D teachers with very different subject backgrounds and students, they were asked to describe their own definitions of the term 'model'. This will provide a frame of reference as foundation for clear and unambiguous communication regarding the concept of 'model' within this context. The concept of a frame of reference, as described in the Cambridge dictionary (2023), refers to a set of ideas or facts accepted by a person that explains their behaviour, opinions or decisions. Developing the frame of reference involves creating and expanding upon this knowledge and experience. To achieve this, the research employed two steps.

Firstly, an initial survey was conducted among students in both the first (22 students) and final years (10 students) of secondary school, as well as among 14 R&D teachers. Only science teachers participated in this design research. However, these science teachers are diverse in terms of their qualifications and the subjects (other than R&D) and levels they teach (lower and upper grades). In this research, no specific conclusions are drawn regarding the composition of the respondent group. The purpose of the first survey was to gather insights into their individual definitions of models, their ability to recognize different forms of models, and their perspectives on the potential uses of models. By examining these perspectives, a comprehensive frame of reference for the concept of 'model' can be established. The questionnaire consisted of three parts.

The first part comprised twoo open-ended questions about models: "What is your definition of a model?", "Why do we create models?" These questions aimed to assess the students' previous knowledge and their own understanding of the concept of models.

In the second part of the questionnaire, pictures of various types of models were presented to the students. They were then asked a closed-ended question for each picture: "Is the following considered a model?" This section aimed to assess the students' ability to recognize and identify different forms of models. The pictures included a scaled model car (1:24 scale), a villa maquette, a playmobil horse, a TV schema, a mathematical formula, an organisational chart, a map of the Netherlands with coloured provinces, a cardboard model of a Vespa scooter, a low-cost kids FM radio circuit diagram, and a stuffed toy animal. Different model representations were selected on three levels of abstraction. Lowest level close to the state of things as they are, middle level when objects are close to the state of things as they are with imaginative elements and high level of abstraction when object is no longer connected to state of thing as they are.

The third part of the questionnaire consisted of a multiple-choice question: "Why do we create models?" Students were provided with various answer options, including "To simplify reality," "To highlight important components," "To test prototypes," "To conduct experiments," "To create small-scale examples," "To learn about something," "All of the above," and "Something else." This section aimed to gauge the students' understanding of the purposes behind creating models.

Secondly, a two-question survey was conducted with five teachers who form an R&D team at another school. The second question of the survey was presented in a multiple-choice format, where participants were asked to select characteristics of a model provided by van Driel and Wegner. The purpose of the survey was to assess the similarities between self-verified characteristics and characteristics drawn from the literature, as well as the choice of characteristics from the literature when given. These teachers have diverse qualifications, and they teach various subjects and grade levels (lower and upper grades) in addition to their involvement in R&D.

Van Driel (1997, pp. 179-180) has provided a set of characteristics that can be used to identify a model in the natural sciences. Additionally, Wegner (2017) emphasises that a model always has a purpose. These sources served as the foundation for the multiple-choice question in the survey. The answers from the first question, "What is a model?", were analysed for their alignment with the characteristics described by van Driel and Wegner. This analysis was conducted using the Atlas.ti method.

4. RESULTS

The first part of the research survey consisted of two open-ended questions about models to assess the previous knowledge of students and teachers, as well as their understanding of the concept of models. The first question: "What is your definition of a model?" reveals an overlap in goal- and example-oriented definitions in all three groups, highlighting that models serve as simplified representations or descriptions of reality and can be used as examples for something. Furthermore, the definitions given were diverse.

The question of why we create models uncovers different perspectives between students and teachers. While students, both in their first and last year, focus on the purpose of models, such as testing or checking their functionality, and emphasise the benefits and advantages of creating them, such as providing visually appealing representations of how something looks or works, teachers, on the other hand, emphasise the clarifying, communicative, and explanatory role of models, as well as the benefits of visualisation that they offer. Even though a definition from literature also clearly plays a role here, namely that the model always has a purpose, Wegner (2017), it emerges that description of the purpose of the model changes with the role that respondent fulfils within the school. The students opt for testing and presentation and teachers for clarification and explanation.

In the second part of the questionnaire, students were presented with pictures of various types of models. This section aimed to assess the ability of both students and teachers to recognize and identify different forms of models with different levels of abstraction. From the answers, we observed that models which are very close to reality such as scaled car models, villa maquettes, cardboard Vespa were recognized as a model by all groups. In the first year, recognition of models mostly remained at level 1, while in the last year there was an increase in recognition, reaching level 3, see table 1. The interpretations among teachers varied greatly and show in % less confidence in recognition of the model than last year students.

Table 1 Results overview - Three-step level of abstraction/reality
1 = low level of abstraction, very close to reality
2 = medium level of abstraction, close to reality thou parts differ from reality
3 = high level of abstraction, a model differs from reality

This is a model. Yes, No, I don't know	abstraction level	22 students first class high school	Nine students last year high school 9	14 teachers from one school
1 Scaled car	1	**yes 73%** no 27%	**yes 100%**	**yes 93%** no 7%
2 Villa maquette	1	**yes 100%**	**yes 100%**	**yes 86%** no 7% , don't no 7%
3 Playmobil horse	1	yes 32% **no 54%** ,	yes 44% **no 56%**	**yes 50%** **no 50%**

		don't no 14%		
4 TV schema	3	**yes 50%** no 45% , don't no 5%	**yes 89%** no 11%	**yes 58%** no 21% don't no 21%
5 Mathematical formula	3	yes 13% **no 73%** , don't no 13%	**yes 56%** no 44%	yes 14% **no 72 %** don't no 14%
6 Organisation schema - organogram	3	yes 5% **no 73% ,** don't no 22%	**yes 56%** **no 33% ,** don't no 11%	yes 28% **no 58%** don't no 14%
7 Map of the Netherlands	2	yes 33% **no 77% ,**	yes 44% **no 56%**	yes 28% **no 50%** don't no 22%
8 Paper vespa	1	**yes 82%** no 9% , don't no 9%	**yes 78%** no 11% , don't no 11%	**yes 64%** no 22% don't no 14%
9 FM radio schema	2	yes 45% **no 45% ,** **don't no 10%**	**yes 78%** no 11% , don't no 11%	**yes 64%** no 22% don't no 14%
10 Stuffed animal toy	2	yes 18% **no 73% ,** don't no 9%	yes 22% **no 78%**	**yes 50%** no 35% don't no 15%

The third part of the questionnaire consisted of a multiple-choice question. This section aimed to gauge the students' understanding of the purposes behind creating models. In all three groups, the majority of respondents selected "To highlight important components" as their answer. Additionally, among the students, two other commonly chosen answers were "To simplify reality" and "To test prototypes."

First characteristic to choose was; "A model is always a model of something, namely of an object of investigation" has been chosen unanimously. Therefore the open question answers were again underlined. Second answer chosen by 80 % of teachers was a; "A model is a tool for research into the object in question." Least chosen answer was; "A model differs from the object of research in that reductions are applied when drawing up a model by scaling or in some other way." This is a very interesting answer because it shows clearly not understanding of changing model level to abstraction.

Table 2
Results of a multiple-choice question

Characteristics of model from literature according to van Driel and Wegner	Teachers answers	Teachers answers overlap characteristics of model from literature
1 A model is always a model of something, namely an object of investigation.	5 x yes	100%
2 A model is a tool for research into the object in question.	4 x yes	80%
3 A model differs from the object of research in that reductions are applied when drawing up a model by scaling or in some other way.	2 x yes	40%

4 A model shows a number of similarities with the object of research	3 x yes	60%
5 A model is not derived directly from the object of study, such as a photograph or a measurement result. It contains elements that the object of investigation does not possess. Creativity therefore plays a role in the choice of a model.	3 x yes	60%
6 A model therefore has a built-in compromise character and the researcher has a certain freedom in choosing a model. The research question plays a role in that choice	3 x yes	60%
7 In the course of a study, a model may undergo an iterative development. The object of research is always studied in more detail.	3 x yes	60%
8 A model should alway has a purpose (for R&D)	3 x yes	60%
100% = 40 Similarity with features offered	65% = 26 Similarity with features offered	

Coding given answers on the open question "What is a model" showed an understanding by 60% of respondents of a model being a model of something (object). Just one respondent (20%) has an overlap with literature drawn characteristics (Van Driel, 1997; Wegner, 2017) mentioning purpose and reality. Although the answers do not correlate to literature they correlate to each other. The word simplified was named unanimously, representation and scale by 60% of respondents. See table 3. Respondents were all from the same school so this could show an already existing frame of reference.

Table 3
Identifying characteristics drawn from literature coding answers from respondents

Respondent	Answer to the open question "What is a model?"
Teacher 1	A **representation** (3D or 2D) of a **scaled**-down object
Teacher 2	A **representation** of the original object to **scale**
Teacher 3	A **simplified** or **scaled**-down **representation** of a real object or concept.
Teacher 4	**A simplified representation** of reality, with the purpose of providing insight into certain properties (such as proportions, functioning mechanisms, etc.).
Teacher 5	A **simplified representation** of a complex system, where there are multiple possibilities/perspectives to depict this system

5. CONCLUSION

The provided results highlight several interesting points regarding the definition and understanding of models among students and teachers. One significant finding is the overlap in purpose and example-oriented definitions of models, emphasising their role as simplified representations or descriptions of something, often referred to as reality. However, the recognition of models remained predominantly at a lower level of abstraction among young students, with an increase in recognition observed among older students.

Surprisingly, the recognition of models among teachers showed unexpected variation, despite the anticipated increase in abstract level recognition among older students. This suggests a potential gap in understanding and knowledge among teachers regarding the recognition and abstraction levels of models.

The majority of respondents, across all three groups, identified "To highlight important components" as the main reason for creating models. Additionally, students commonly chose "To simplify reality" and "To test prototypes" as their reasons for making models.

The second survey aimed to compare the characteristics of models found in literature with those named by teachers. It revealed that teachers understood a model to be a representation or model of something, often referred to as reality. The majority of teachers agreed with the statement that "A model is always a model of something, namely of an object of investigation." But at the same time they do not recognise that the model could be different from reality.

Although we can detect similarities between the teachers of the same school on the definition of concept of model, those similarities are a fraction of the available knowledge about the models' goals and definitions. These findings indicate a need for broadening and deepening the set of values, norms, and knowledge among R&D teachers regarding the definition and use of models. Providing teachers with more comprehensive knowledge about the characteristics of models, considering the lack of unanimous choice among the provided definitions, is crucial to establish a common frame of reference and enhance their ability to teach students effectively. Furthermore, the absence of unanimous answers about what a model is and why we make one suggests a potential need for cross-disciplinary courses for teachers in STEM subjects to foster a more cohesive understanding of models across disciplines. The conceptual understanding of the term 'model' among R&D teachers with very different subject backgrounds, within this pilot, is incomplete and ambiguous.

6. DISCUSSION

It is clear from this pilot study that R&D teachers lack unambiguous knowledge about the concept of model. Regardless of the number of similarities in answers there are many differences in answers to ignore a lack of knowledge. Comparison between different R&D teams from different schools can provide more clarity about similarities which may be related to school. Abstraction level of the models is not further explored focusing on recognizing purpose and definition of a model.

Nevertheless, focusing on high abstraction level models which differ from reality could be interesting for further research and provide a frame of reference which can connect a curriculum and learning about models in R&D.

This pilot enriched us with knowledge about the narrow frame of reference within R&D teachers regarding model characteristics and purpose. It does not provide an answer why that is so and how we can solve it. It just indicates a problem which might occur in more heterogeneous STEM subjects' communities.

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Characterising Structure-Property Reasoning within a Chemical Design Challenge: 'Green Bubble Soap'

Sebastiaan de Lavoir, Delft University of Technology, s.v.p.delavoir@tudelft.nl
Marie-Jetta den Otter, Delft University of Technology, m.j.denotter@tudelft.nl
Marc de Vries, Delft University of Technology, m.j.devries@tudelft.nl
Erik Barendsen, Radboud University, Nijmegen / Open University, erik.barendsen@ru.nl

ABSTRACT

Where design seems to merge easily with physics or technology education, it does not seem to take place in secondary chemistry education. Design is one of the crosscutting concepts between the different STEM subjects, (Science, Technology, Engineering, Mathematics) and is therefore included in curricula and standards in many countries. Function-Behaviour-Structure (FBS) reasoning is an important design skill. In a chemical context it shows similarities with structure-property reasoning (SPR). This SPR is a common practice for chemical engineers but difficult to learn for secondary students. Given the similarities, chemical design activities might be a way to enhance students' SPR. Moreover, SPR might be a useful tool in the FBS framework when evaluating behaviour derived from a micro level structure. We describe an explorative study in which the design of bubble soap is used as a context to promote students' SPR. Data was collected in the form of audio recordings of student conversations within the design team and their design drawings on worksheets. Qualitative analysis, using the perspective for SPR as a framework, revealed that identified SPR was expressed in three ways: as a link between structural features and substances, as a link between the term 'molecule' and property and as a link between molecular structures and properties of a substance. Furthermore, analysis showed that SPR was only found during evaluation, discussion and ideation stages of the design process. The results indicate that this chemical design project can be used to stimulate students' SPR and that SPR can be related to processes of the FBS framework.

Keywords: Structure-property reasoning, Function-behaviour-structure thinking, Design-based learning, Chemical Engineering.

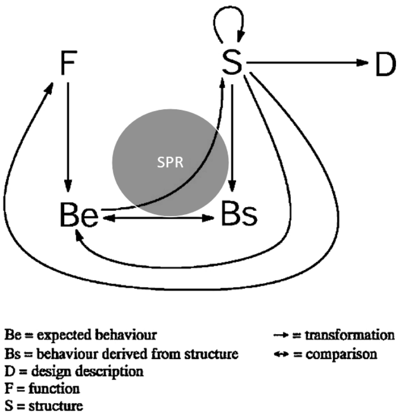
1. INTRODUCTION

In the last decades, design-based teaching approaches have gained significant attention from researchers. Design has been part of STEM curricula in many countries (NGSS, 2013; CvTE, 2022). Design activities serve as a vehicle for teaching and learning science concepts within a problem-solving context (Fortus et al., 2004; Apedoe et al., 2021). In some cases, these activities can be more effective than a scripted inquiry (Mehalik et al., 2008; Guzey & Jung, 2021).

Furthermore, design activities can lead to improvement of students' scientific reasoning (Chusinkunawut et al., 2021). The design process consists of different stages such as 'identification and research of the problem', 'ideation', 'constructing and testing the prototype', 'discussing results' and 'evaluating the test outcomes'. Students' reasoning varies throughout these different stages (Aranda et al., 2020). STEM education can also contribute to the learning of design skills in different contexts. Therefore, integrating design in STEM education benefits both ways (Li et al., 2019). The technoscientific nature of chemistry, one of the science disciplines in STEM education, is manifested in the core practices of chemical engineers: design and synthesis of molecules and materials, exploring novel synthesis routes, analysis and optimisation of processes, all for people to extend their abilities and to satisfy their needs and wants (Talanquer, 2013). A biochemical engineering example is the synthesis of liposomes for controlled drug delivery (Nguyen et al., 2014). Design activities therefore can serve as an authentic practice to involve secondary students in the way chemical engineers think and do. But where design seems to merge easily with physics and technology education it does not seem to take place much in upper secondary chemistry education (Roehrig et al., 2012; Stammes et al., 2020).

In technology and engineering design, Function-behaviour-structure (FBS) thinking is an important concept. The FBS framework (figure 1) describes a way of relating structural components of a design to their function and the mechanisms that enable them to perform their functions (Gero & Kannengieser, 2004). The FBS framework describes processes that connect the function variables (what is it for?), via the expected- and structure-derived behaviour variables (what it does), with the structure variables (what it is) to eventually end up with a design description. Different from engineering design, in a chemical design activity the processes of evaluation and synthesis require reasoning about the structures on a non-observable molecular level, emergent observable properties at macro level and then linking these with expected- and structure-derived behaviour. Furthermore, chemical engineers hypothesize what structures at micro level can account for the desired properties of a material at a macroscopic level (Sevian & Talanquer, 2014). By providing explanations or predictions in this manner, they apply what is called 'structure-property reasoning' (SPR). SPR is a chemistry-authentic practice and it is embedded in many chemistry curricula (NGSS, 2013; CvTE, 2022). Chemical engineers use this way of thinking seemingly easy, but structure-property reasoning is difficult to master for novice learners (Chi et al., 2012; Johnstone, 1997).

Figure 1.
The FBS framework adapted from Gero & Kannengiesser (2004). The grey sphere indicates where SPR is situated within the FBS framework.



A good understanding of structure-property relations can help students to better understand chemistry concepts (Talanquer, 2018) and make better design decisions. The similarity of structure-behaviour-function thinking in design and SPR in chemistry might provide a possibility to integrate design into chemistry classrooms and stimulate students' SPR. Moreover, SPR may provide a useful tool in the FBS framework when evaluating design behaviour in relation to molecular structures. A way to introduce SPR is by using perspectives as a lens to approach an observable phenomenon. In general, a perspective guides the students in asking questions and assessing their answers by *"...lighting up a certain aspect of the real world and directs the research on those aspects."* (Janssen et al., 2020 p.255). The perspective for SPR provides specific questions to guide students' reasoning from macro level to micro level (Den Otter et al., 2021). An adapted version of this perspective (figure 2) can serve as a framework to characterize students' expressions.

Figure 2.
Perspective for Structure-Property reasoning.

Students' way of reasoning cannot be investigated directly. We can only look at representations of their thoughts. In the situated FBS framework drawings, for instance, are referred to as the 'externalised expected structure' (Gero & Kannengieser, 2004). The students' drawings of molecular structures and their speech, represent the way the students think about matter on a macro or micro level and can provide information to assess students ways of chemical thinking (Taber, 2013, Stammes et al., 2023). However, specific research on secondary students' SPR during engagement in chemical design activities is scarce.

For our studies purpose, a project around the design of bubble soap was used, as we will describe in section 2.1. Bubbles find a technological application in drug delivery, food technology and waste water treatment (e.g. Kaushik & Chel, 2014). In this paper, we describe a small scale explorative study we performed to gain more insight in students' SPR while engaged in this specific design challenge, called 'Green bubble soap'. We aim to answer the following questions:

- In what way can students' identified structure-property reasoning be characterized during engagement in the chemical design activity 'Green bubble soap' in upper secondary chemistry education?
- What relationship can be identified between students' structure-property reasoning and the different stages of the chemical design project 'Green bubble soap'?

2. METHODOLOGY

2.1. Context

The project 'green bubble soap' was used to teach in a 10th grade secondary chemistry class two obligatory parts of the syllabus: solubility of compounds and design skills. This was done during three subsequent, regular time-tabled lessons of 45 minutes in May 2023:

(i) Lesson 1: An introduction on design in general, an introduction of the project, the demands of the desired product and generating ideas on volume-ratios of water-soap mixtures.

(ii) Lesson 2: A small experiment to guide students' thinking about the behaviour of soap molecules in water. Building and testing of the artefact, discussing the results with the teacher, redesign and generating ideas.

(iii) Lesson 3: Building and testing the final prototype and wrap-up of the project: What is the recipe for the best bubble soap, the design description. How to become the Bubble Boss?

The goal of the design project was to identify the recipe for the perfect bubble soap with sustainable / natural ingredients. The definition of 'perfect' was first established and came down to "long lasting bubbles". Students had to specify the required properties of the bubble soap, the expected behaviour, and subsequently propose ideas for an additional ingredient besides water and soap to better meet the expected behaviour. While generating ideas or evaluating test results, students were encouraged to explain their decisions with the use of SPR.

2.2. Participants

All of the participants were connected to a secondary school in an urban area in the west of the Netherlands. Convenience sampling was applied for our study in which we focus on two student teams. Each team consisted of 2 male students aged between 15 and 17 years old (n = 4). The teacher guiding the design challenge works as chemistry teacher in that school, and is the first author of this article. He holds a master's degree in chemistry, is qualified for teaching upper secondary chemistry classes and has 14 years of teaching experience. The two student teams were chosen for being 'easy talkers'. Since we want to capture representations of thought, we wanted to gather as much talk within a group as possible within a lesson. The two teams were asked to cooperate and were fully informed about the purpose of our study, the way the data was collected and stored, and they subsequently gave their consent.

2.3. Data collection

We collected the data during the second lesson because this lesson was the most student-centred lesson of the three. Therefore, this lesson would generate the most student talk during the different stages. We asked students to express their thoughts out loud. The talks within each team and with the teacher was audio recorded and transcribed verbatim. In addition, we used a set of worksheets per team (Stammes et al., 2023) for students to draw and sketch their micro-level structures on. Furthermore, the worksheets had pre-structured questions for students to answer, to guide the design process. The students' worksheets with drawings and written reasoning were digitalized as pdf-file.

2.4. Data analysis

First the transcripts were divided in sections and marked according to the different stages of the design process, using ATLAS.ti. After that, a deductive coding approach was employed where the transcripts were recoded using questions of the perspective for SPR (figure 2) as an analytical lens.

Table 1.
Examples of students' expressions underlying the applied codes.

Codes	Example of students' expression
Macro – substance	"*we take water and soap*"
Macro – organisation	"*bubble" / "we got layers" / "3 millilitre and 7 millilitre ratio*"
Macro - property of substance	"*sugar is hydrophilic" / "it dissolves well*"
Micro – type of particle	"*The water molecules…" / H's and O's*"
Micro – interaction	"*They have strong bonds*"
Micro – organisation	"*We have 2 water molecules on 1 soap molecule*"
SPR	"*A lot of bonds to be hydrophilic, a lot of O-H bonds, or N-H*"

Students worksheets and drawings were coded using the same approach. First by stage of the design process and then recoded using the perspective for SPR. The selected quotes and applied codes were discussed between the first and second author until a consensus was reached about whether a quote was to be selected or not and whether it expressed thoughts on a micro level, macro level or SPR. If no consensus was reached, the quotes were left out of the analysis. The code co-occurrence tool in ATLAS.ti then revealed in what stages of the design process SPR codes occurred.

Subsequently all quotes with the applied code 'SPR' were grouped and axial coded to uncover themes and characterize the expressed reasoning.

3. RESULTS AND DISCUSSION

3.1. Characterizing the identified SPR

Our first research question was: In what way can students' identified structure-property reasoning be characterized during engagement in the chemical design activity 'Green bubble soap' in upper secondary chemistry education?

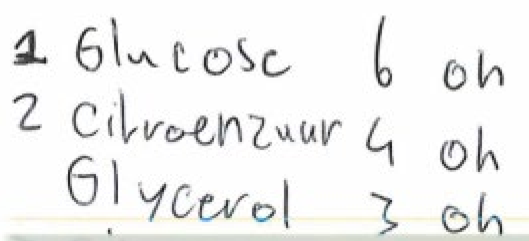
Analysis of the fragments with the applied code 'SPR' revealed that it was expressed by students in one of three following ways:

3.1.1. A link between substances and their structural features.
The first category of students' SPR expressions contained a link between a substance and the structural features or characteristic moieties of the molecules. The following quote provides an example.

Student 1: You want one with O-H bonds, right? Well, then there is glycerol, citric acid.

When looking at the FBS framework, this type of thinking emerges in the proces of reformulation of the structure when new structure variables are introduced. They also annotated it on their worksheets with ideas:

Figure 3:
Annotation of ideas for substances on the worksheet, ranked by the number of OH-groups in the molecule. [citroenzuur] means citric acid.



3.1.2. A link between the term '...molecule' and properties.

The second category we identified contained verbal or written expressions in which macro level properties were attached to specific molecules.

> "A soap molecule can dissolve with one or two water molecules"

In this example, the property 'dissolving' is linked to the micro-level term 'soap molecule'. This expression was used by students to explain an observed test result, which in the FBS framework aligns with the process of evaluating expected- versus structure-derived behaviour.

Or as students described on their worksheet :

> The hydrophobic part of the soap molecule pushes the pepper to the side.

In this excerpt students describe an observed behaviour: the pepper floating on a water surface in a bowl being pushed to the sides when a drop of bubble soap is added. They link the property hydrophobicity to a part of the soap molecule. Moreover it explains for them a structure-derived behaviour.

3.1.3. A direct link between structural features and the properties.

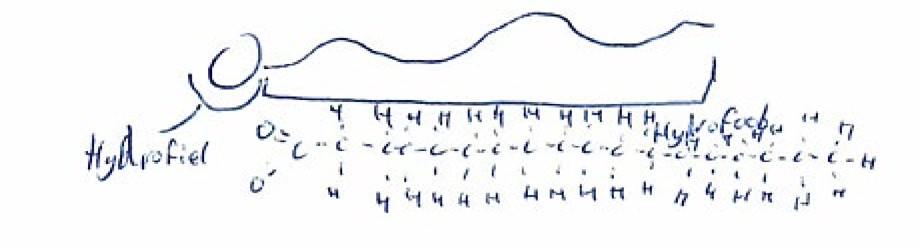
When evaluating the test results of their prototype, and subsequent ideation, group 1 expressed a direct link between structural features and properties in the following way:

> Student 2: A hydrofobic compound, a hydrophilic compound I mean.
>
> Teacher: A hydrophilic compound, So you're looking for a molecule that...What requirements does such a molecule have to meet, when it is hydrophilic?
>
> Student 2: A lot of bonds to be hydrophilic, a lot of O-H bonds, or N-H"

In the example above we see that the identified SPR was guided by the teacher. The reasoning itself began at macro level property, 'hydrophilic', via statement at micro level interaction, 'bonds', to statements at micro level about structural features of the desired molecules. In relation to the FBS framework this describes the process of synthesis: going from expected behaviour to structural features.

We also saw this structure-property link, hydrophobicity and a branch of C-atoms in the structure, in an annotated drawing (figure 4).

Figure 4. Annotated drawing of a soap molecule. [hydrofiel] means hydrophilic and [hydrofoob] means hydrophobic.



3.2. SPR per stage of the design project

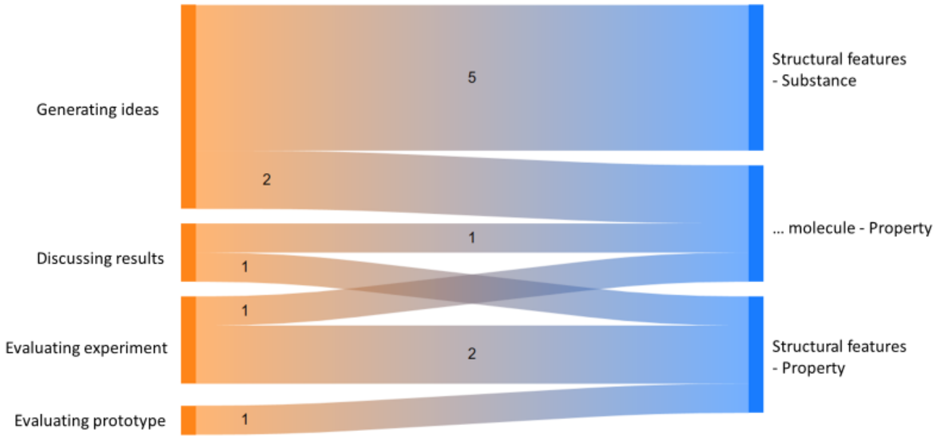
The second research question guiding our analysis was: What relationships can be identified between students' SPR and the different stages of the chemical design project 'Green bubble soap'? We identified (grey in table 2) many expressions about the micro and the macro level, but only in four stages of the design project SPR was identified. When performing the experiment, building the prototype, and testing the prototype students expressed no direct SPR.

Table 2.
Identified micro level, macro level and SPR expressions per stage of the design process.

	Macro - organisation	Macro - property	Macro - substance	Micro – Type of particle	Micro - interaction	Micro - organisation	SPR
Evaluating prototype							
Generating ideas							
Evaluating experiment							
Performing experiment							
Prototype building							
Prototype testing							
Discussing results							

3.2.1. Stages of the design project in which SPR was identified
As described in section 3.1, identified students' SPR could be divided into three categories: a link between structural features and substances, a link between the term 'molecule' and properties and a link between structural features and properties. The structural feature – substance link was only found in the stage of generating ideas (figure 5).

Figure 5.
Sankey diagram of stages of the design activity in which SPR links were identified.



When generating new ideas, students in group 1 used structural features to select the ingredient that they thought would improve their design. They then compared the molecular structures of the substances given, to select the molecule with the highest amount of hydroxyl groups as being the best candidate to meet the expected behaviour.

> Student 1: Structure formula. You want one with O-H bonds, right? Well, then there is glycerol, citric acid.
>
> Student 2: No, regular salt is not going to work.
>
> Student 1: glucose has H's. [looking up structures on their smartphones]
>
> Student 2: Glucose, WOW! That's the one, that's the one! All right.
>
> Student 1: no, no, we keep that one in mind. How many OH?

The students remained in the stage of generating ideas and weighing all compounds to make sure one of the candidates stands out as being the best one.

In contrast, when we looked at group 2, no SPR was observed in the stage of ideation. In this stage they stuck to the macro level descriptions of substances and rushed into the stage of building and testing their new prototype.

> Student 3: Shall we just begin with sugar? I always used to do it with sugar in it.

Student 4: You always used sugar?

Teacher: …

Student 4: Yes, let's just do that."

In the stages of evaluating the prototype, evaluating the experiment, and discussing results, students gave meaning to their observations. In this stage we found explicit links between properties of substances and micro level structures or the term '…molecule' (figure 4). An example is stated in the quote in section 3.1.3 where 'hydrophilic' is linked to O-H or N-H bonds in a molecule.

3.2.2. stages of the design project in which no SPR was identified
Performing the experiment and building and testing of the prototypes were the more hands-on stages of the design project. In these stages no SPR was identified.

4. CONCLUSIONS

The aim of this explorative study was to investigate how students' structure-property reasoning could be characterized during engagement in this specific design activity. Furthermore, we looked at the link between the expressed SPR at different stages of the design process.

In answer to our first research question, we can state that students' expressions of SPR emerged within one of 3 ways:

- As a link between structural features and substances
- As a link between the term '…molecule' and property of a substance
- As a link between molecular structures or characteristic moieties and the property of a substance.

Almost all of the SPR coded fragments were found in the data of group 1. In group 2 the only expression of SPR was found in an annotated drawing on one of the worksheets (figure 4). This confirms the added value of using multiple sources of data when looking at students' thinking during design activities (Stammes et al., 2023).

In answer to our second research question, we saw that SPR was expressed in stages of the design activity in which students gave meaning to their test results and when they generated new ideas. These are processes similar to evaluation, synthesis and structure reformulation in the FBS framework. In these stages students were stimulated to provide explanations and employed evaluative thinking, divergent and subsequent convergent thinking as seen in engineering design (Guzey & Jung, 2021). The function, which states the design requirements was never a topic of debate amongst students.

The project ‘Green bubble soap’ can be used to investigate students’ SPR. The next step will be to use the described method on a larger scale in the context of a professional learning community. By measuring in different classrooms, we can investigate to what extend our results are transferable to other settings and do a more sophisticated analysis of the expressed SPR. Furthermore, with a broader dataset we can closely look into ways to characterise SPR within the FBS framework processes and how it can guide design thinking and thinking about complex systems. By gaining more insight in the way students use this type of reasoning during a design activity we can look at ways to integrate chemical engineering in multidisciplinary design activities in secondary education.

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Teaching Variables and Functions at the Secondary Level in a STEM Context

Brahim El Fadil, Université du Québec en Abitibi-Témiscamingue, elfadilb@uqat.ca
Ridha Najar, Université du Québec en Abitibi-Témiscamingue, ridha.najar@uqat.ca

ABSTRACT

STEM education is becoming more popular at the primary and secondary levels in many curricula around the world. Effective instructional STEM activities and design methods are required to ensure that students' and teachers' needs are being met. One potential method is the Technology Design Process (TDP): a methodology that stresses the importance of creativity, collaboration and being open to adjustments and compromises. This article reports on a case study that focused on the use of TDP to design and develop teaching-learning materials based on pendulum experiments to introduce variables and functions in mathematical context at the secondary level. The five iterative stages of TDP were integrated into the development of the course materials. Data was collected from 20 high school students who participated in a STEM activity. Both pre- and post-questionnaires were administered to the students. Additionally, a working document was used to assess the students' understanding of abstract concepts and the TDP. The results indicate that TDP-centred activities effectively promote critical thinking, encourage questioning, and facilitate meaningful exploration of abstract concepts.

Keywords: STEM activities, TDP, variables and functions, motivation, pendulum motion.

1. INTRODUCTION

Several researchers have emphasized the effectiveness of inquiry-based thinking activities is enabling students to apply their prior knowledge from different fields to new learning situations that model problem-solving processes. However, it has been observed that many teachers struggle to effectively integrate hands-on activities with engaging cognitive processes during instruction (Nisa, 2021). To bridge this gap and establish meaningful connections between teaching and learning, particularly in the context of technology education (TE), innovative techniques are required to address real-life challenges. Besides, the incorporation of engineering concepts into secondary education, as emphasized by the ITEEA (2007), has broadened the scope of STEM integration beyond just science and mathematics.

Moreover, Dym (1999) highlights that the TE curriculum places a strong emphasis on the TDP, which is an interactive, creative, and practical approach that promotes critical thinking skills. This curriculum encourages integrative learning, which transcends traditional academic boundaries and encourages students to tackle real-world problems and consider diverse perspectives. It is essential to educate students about STEM epistemic practices (Bevan et al., 2019), the principles of technology (Mitcham, 1994) and their integration with other subjects to validate this interdisciplinary approach (Wells, 2019).

In the province of Quebec, the curriculum integrates Science and Technology within the same discipline, while mathematics remains a separate subject. It is important to note that in the Quebec Education Program (2006), the term "Technology" refers to TE. Integrating STEM content within TE is a relatively new practice in the Quebec context. Currently, it is only available in a limited number of schools as elective programs, such as robotics or science and engineering. Moreover, El Fadil et al. (2018) show that the TDP, in Quebec context, is often found to be more technical. Their survey reveals that science and technology teachers have varying understandings of this process, resulting in inconsistencies in its implementation in their classrooms. This confusion could be attributed to factors such as curriculum ambiguity, inadequate teacher training, or a lack of standardized measures for integrated learning.

This proposal aims to introduce seventh-grade students to the concepts of variables and functions through a physics activity centred around TDP. There are two main justifications for focusing on these concepts at this level: historical significance and curricular relevance.

From the historical perspective, the concept of function has long been recognized as crucial in mathematics, with its origins traced back to Galileo's investigations into the motion of a pendulum. Galileo identified variables and explored their quantitative relationship, which led to the emergence of a preliminary definition of a function as an algebraic expression representing the relation between variables (da Ponte & Henriques, 2013).

As part of the curriculum, seventh-grade students have not yet been formally introduced to functions in mathematics or to TDP in technology. This level provides an appropriate opportunity to engage students in STEM activities that incorporate these concepts. By introducing this project, we ensure that students' prior knowledge does not influence the data collected during the study.

1.1. Research questions:

- To what extent do STEM activities enhance students' understanding of both mathematics and TDP?
- How do STEM activities impact students' motivation to grasp abstract concepts and actively engage in technological problem-solving processes?

2. CONCEPTUAL FRAMEWORK

This study draws its foundation from the Haupt (2018) model, which incorporates diverse pedagogical approaches and underlying philosophical conceptions that shape observed teaching practices. The framework considers pedagogy from a practical standpoint, encompassing three modes of transfer: cognitive constructivism, social constructivism, and the technological mode.

Cognitive constructivism focuses on individual performance, emphasizing internal rigor and knowledge construction through the utilization of teaching strategies (Williams, 2016). Social constructivism emphasizes the construction of knowledge through external and social elements, involving interactions with teachers and peers. The technological mode highlights teaching that is facilitated and supported by digital tools and methods.

The philosophical conceptions include four subcategories: epistemology, ontology, methodology, and values (De Vries, 2019; Mitcham, 1995; Svenningsson, 2019). Epistemology relates to the types of knowledge and their sources necessary for designing. Ontology pertains to the nature of mental processes, types of thinking, and psychological characteristics involved in designing activities. Methodology addresses themes centred around the TDP and suggests the structuring of design procedures and strategies. Values encompass soft skills, attitudes, efficacy judgments, ethics, the impact of technology and artifacts, social awareness, cultural, environmental, technical and economic values, as well as environmental sustainability (Haupt, 2018).

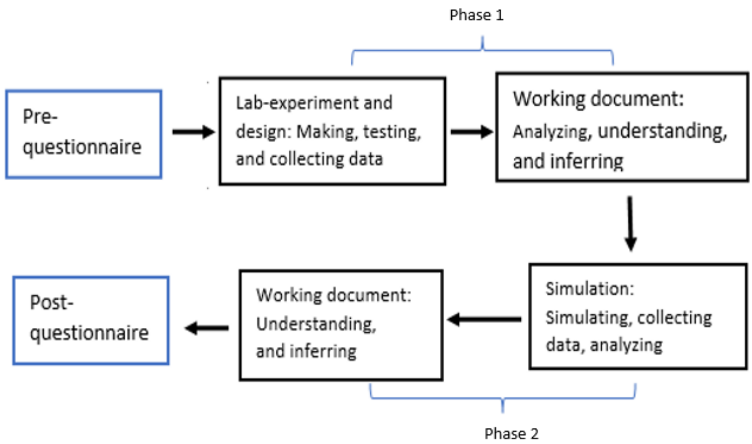
3. METHODOLOGY

To promote transdisciplinary learning through the TDP, our initiative started with a physics activity centered on pendulums. This is justified by the fact that physics not only has natural connections with engineering and technology, but also possesses the capacity to initiate interdisciplinary dialogues and methodologies that transcend traditional disciplinary boundaries (Sinatra et al., 2015).

The project involved designing, making, and analyzing a pendulum, using two teaching phases outlined in Figure 1. The aim was to gain insight into the interrelationships among the variables of the pendulum. Data was collected from a seventh-grade classroom with 20 students. We understand that the number of participants in our study is insufficient to achieve representativeness or support in-depth statistical analysis. This limitation stems from the restricted access to schools due to the ongoing COVID-19 pandemic.

To ensure the credibility of our findings, we followed a case study design and used multiple data sources (Yin, 2003). These sources included pre- and post-questionnaires, hands-on observation during the TDP, as well as a working document that captured students' understanding.

Figure 1.
Project phases of implementation (Source: El Fadil & Najar, 2022)

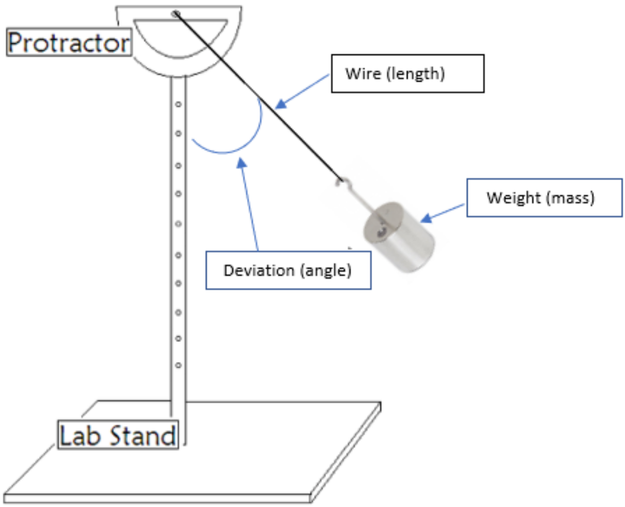


The first phase focused on designing, making and testing of a simple pendulum to explore its function and the variables involved. It began by assessing students' prior knowledge through a pre-questionnaire designed around three fundamental principles: (1) Mitcham's typology of technology, which encompasses objects, activities, knowledge, and volution (Mitcham, 1994); (2) STEM epistemic practices, including investigating, sense-making, and critiquing (Bevan et al., 2019); and (3) content derived from the Mathematics, Science, and Technology subject area in the Quebec Education Program (2006). Students then designed, made, and tested the pendulum using lab-tools to measure its variables. They worked in small teams and generated ideas for designing a simple pendulum, considering the key factors that influence its swings. During a group discussion, students identified mass, length, period, and deviation (angle) as important factors to consider in analyzing the pendulum's behavior. Furthermore, they identified mass, length, and angle as variables that can be controlled (independent variables), while the period of oscillation is identified as the dependent variable, which cannot be controlled.

To explore the relationship between these variables, students were assigned the task of investigating the impact of an independent variable on the period of the pendulum. Collaborating in teams, students engaged in designing, creating, and testing simple pendulums, utilizing a variety of technological tools.

To gather data on the effect of length, students designed pendulums with various lengths of 30 cm, 40 cm, 50 cm, 60 cm, and 70 cm. For each length, they conducted three measurements and calculated the average. Subsequently, they changed the wire (length) and repeated the measurement process. Figure 2 provides further details on this experimental setup.

Figure 2.
An Example of a Simple Pendulum Design



To gather data on the impact of the mass as an independent variable, the group designed a pendulum with a fixed wire and varied the weights suspended to its free end. They used weights of 20 g, 50 g, 100 g, and 200 g. Regarding the angle as a variable, students encountered issues with the stability of the setup, which resulted in the cancellation of its experimentation. After completing the design activities, the students answered questions related to graphical analysis and extrapolation.

In the second phase, students used a simulation tool available on the platform phet.colorado.edu/ to simulate pendulum motions and gather data, replicating the physical experiments conducted in phase 1. The students were prompted to think critically about the accuracy of their results and the ability to draw valid inferences about the relationship between independent and dependent variables. To evaluate the impact of the design activities on the students' understanding of variables, functions and the TDP, a post-questionnaire was administered.

4. RESULTS AND DISCUSSION

The first category of questions in the pre- and post-questionnaires addresses pupils' prior knowledge about pendulums and how they work. Here is a sample of questions provided in the first category:

- Do you know what a pendulum is?

- Can you explain how a pendulum works?
- What type of energy do you think causes pendulums to move?

Data collected from the pre-questionnaire indicates that out of the 20 respondents, only one student did not know what a pendulum is. However, the remaining 19 students confirmed their familiarity with the concept of a pendulum, although many of them struggled to identify its components. Also, only 6 out of 20 respondents were able to accurately identify the parts of a simple pendulum and correctly associate its function with the swinging motion.

Regarding the variables and the type of energy involved in a pendulum motion, only one out of 20 students showed a limited recognition that the mass of the suspended weight and the length of the wire are variables. Similarly, only one student made a connection between energy and the gravitational force.

The second category of questions focuses on scientific and mathematical concepts that are essential to understanding the physics of pendulums. Here are some questions from the second category:

- Explain in your own words what the term "variable quantity" means.
- What method or technique can you use to describe or represent a situation involving two variable quantities?
- Can you determine which variable is considered the independent variable and which one is the dependent variable in a situation where two variables are involved?

In contrast to the first category, the second category of questions display varying levels of understanding. Regarding the meaning of "variable quantity," eight students mentioned that it refers to a quantity that can change. One student stated that it signifies an unknown quantity, another mentioned that it is an expression used in algebra, while the remaining students had no idea about its meaning.

With reference to the method that can be used to represent a situation involving two variables, two students mentioned charts and graphs, while another student mentioned algebraic equations.

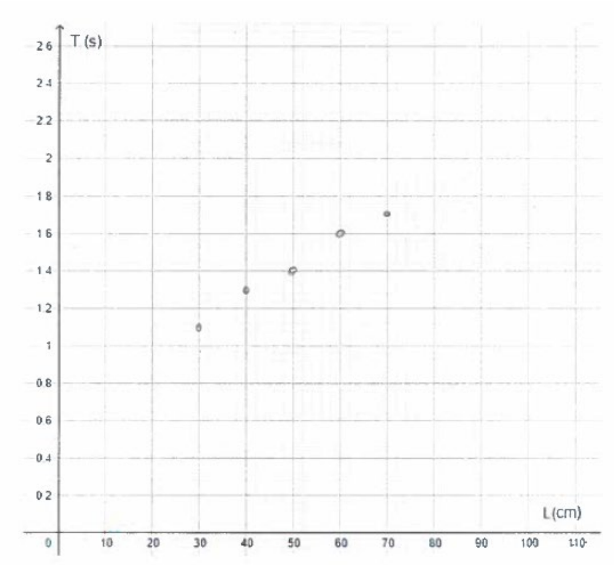
Regarding the ability to distinguish between variables, only 3 students claimed that they can correctly identify which variable is independent and which one is dependent.

The working document provided to the students contains a series of questions that specifically relate to both the process of collecting data from a designed experiment, and how to effectively organize this data into table of values and graphs to make a successful analysis. After designing and making their pendulums, students collected data on length-period variables (excerpt in table 1 and Figure 1). Therefore, they plotted correspondent graphs.

Table 1.
length-period collected data

L: Pendulum length (cm)	30	40	50	60	70
T: Period (s)	1,1	1,3	1,4	1,6	1,7

Figure 3.
Length-Period graph



To gain insight into the students' analysis abilities, we instructed them to use their tables and graphs as references to examine the relationship between the two variables (Length & Period). This task aims to assess not only their proficiency in interpreting and analyzing data based on the visual representations created, but also their ability to think outside the box, by using extrapolation and inference.

The pre- questionnaire's responses indicate that 14 out of 20 students demonstrated the ability to extrapolate their graphs to predict periods for some hypothetical pendulums. For instance, we asked them to determine the periods of the 20-cm-pendulum, 55-cm-pendulum, and 90-cm-pendulum. After analysis, it became evident that the 14 students were able to formulate acceptable answers, as depicted in excerpt 2 (figure 2).

Table 2.
Period Extrapolations and students' answers

Can you determine, from the graph 1, the oscillation period T of	
	Students' answers
a 20-cm pendulum?	T = 1 second
a 55-cm pendulum?	T = 1,5 second
a 90-cm pendulum?	T = 1,9 second

To investigate the relationship between mass and period, students conducted a second experiment. They made another simple pendulum with a fixed length and suspended successively various weights at its free end. The responses indicate a similar level of understanding among the students as in the previous experiment, with the exception that the period varies only slightly as a function of the mass.

The incorporation of digital tools as virtual laboratories has proven to be beneficial for students in enhancing their comprehension of abstract concepts. In the second phase, students replicated the same experiments conducted in phase 1, but in a virtual environment. This activity provided students with an opportunity to reflect on the advantages and limitations of physical laboratory experiments, simulations, as well as modelling. Through this second phase, students learned how the virtual environment empowers them to surpass the limitations imposed by the physical constraints of the lab-equipment. It allowed them to explore and push the boundaries of their knowledge in ways that may not have been possible in the traditional lab setting. The responses indicate that 14 out of 20 students successfully collected data from the simulation platform, generated graphs, extrapolated data, and provided answers to related questions.

After completing the second phase, we administered them the post-questionnaire. The analysis of the post-questionnaire data reveals that all students had acquired a comprehension of the steps involved in the TDP and had a clear understanding of both what a simple pendulum is, and how it works. Additionally, 16 respondents demonstrated an understanding of the connection between the function of a pendulum and the period of its swings, which is influenced mostly by the length of the wire.

However, the analysis of both the post-questionnaire and the working document indicates that only two out of the 20 students were able to make a correlation between the force of gravity and the potential energy involved in the oscillating motion of the pendulum. To gain a deeper understanding of the impact of this project on mathematics learning, we included a question about the inverse function in the working document. We prompted the students how they could make a pendulum that would achieve a specific period of oscillation. For instance, we inquired whether they could calculate the length of pendulums that oscillate respectively with periods of 1.00 s, 1.40 s, and 2.00 s.

The responses indicate that 11 out of 20 students have used their graphs by initiating their lines from the y-axis, which represents the period, to determine the lengths (on the x-axis) of the three hypothetical pendulums, as demonstrated in excerpt 3 (Table 3).

Table 3.
Inverse function questions and students' answers

Can you determine, by using graph 1, the length L of pendulums that have different periods of oscillation?	
	Students' answers
a 1,0-second pendulum?	L = 20 cm
a 1,4-second pendulum?	L = 50 cm
a 2,0-second pendulum?	L = 70 cm

5. CONCLUSION

Integrating technology-driven activities centred around pendulum motion into the TDP framework can significantly enrich students' learning experiences by fostering collaboration and facilitating hands-on exploration. These activities offer students opportunities to design, manipulate, and develop problem-solving skills while gaining a deeper understanding of concepts such as variables and functions.

By engaging in design and hands-on explorations, students have the opportunity to enrich their comprehension not just of the TDP but also of the principles governing simple harmonic motion and variables, particularly focusing on the relationship between the period and the length of the pendulum. Active engagement in TDP-centred activities empowers students to create innovative solutions, analyze data, identify models, and establish connections between variables. This experiential learning approach encourages critical thinking, questioning, reasoning, and meaningful exploration of concepts. Additionally, collaboration among students during these activities provides opportunities for peer learning. Students can share ideas, discuss their observations, and work together to solve problems and explore different approaches. This collaborative learning environment nurtures communication skills, teamwork, and the ability to consider multiple perspectives. Overall, the inclusion of STEM activities in the TDP context empowers students to actively engage in their own learning, develop a deeper understanding of STEM concepts, and build essential skills that can be extended beyond the classroom.

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Transferring Knowledge from One Context to Another

Nina Emami, KTH Royal Institute of Technology, nemami@kth.se

ABSTRACT

This current case study examines the knowledge expressed by students in grade 9 (14-15 years old) when they have been taught about a specific technical system, the wastewater system, and are then asked to describe another optional technical system. They have been taught about the wastewater system through activities such as drawing their own system model and receiving specific guiding questions. In the case study, three students were interviewed after being taught about the wastewater system, and during the interview, they were asked to describe another optional technical system. They drew a system model and described the chosen system. The students' descriptions and their drawn models constitute the data in the case study. The data has been analyzed with transfer theory, and the results are discussed in relation to previous research on certain interpretations of transfer. The results show that the students describe structure and flow. A linear thinking is transferred to the students' descriptions of the new technical system, which may indicate that the relatively linear structure of the wastewater system is transferred to the new system, which, however, has a more circular structure. In conclusion, this study highlights the importance of equipping students with effective learning strategies for comprehending and describing various technical systems. The findings emphasize the need for additional guidance to facilitate the generalization of system knowledge, particularly when transferring knowledge between systems with different structural characteristics.

Keywords: Transfer, technical systems, self-drawn system models.

1. INTRODUCTION

The ability to generalize and transform previously learned knowledge into a new context is important in today's rapidly changing society, where demands and technologies are constantly evolving. The goal is to leverage existing knowledge and experience to solve new problems and address new challenges, rather than starting from scratch every time. This saves time and is beneficial for the individual. By acquiring new skills and abilities, students increase their competence, which in turn can contribute to improved performance and knowledge development and deepening based on previously acquired knowledge (Schwartz, Chase, & Bransford, 2012).

Within educational research, this phenomenon is referred to as "transfer of knowledge”. The idea is that a deeper understanding of transfer is important for designing learning activities that allow students to apply their knowledge of a technical system and thereby improve their ability to learn about another system. Empirical material consists of interviews and students' own system models.

The term transfer (Jensen, 2006) is used to describe various phenomena or processes in different scientific and academic disciplines. It can be positive transfer, where previous learning facilitates new learning, or negative transfer, where previous learning hinders or complicates new learning.

The idea that knowledge and skills acquired in one context should be useful in another context other than the original one is grounded in most learning situations.

2. LITERATURE REVIEW

2.1. Knowledge transfer

Knowledge transfer is an important part of education in schools. Transferring can be done in various ways. This process of knowledge transfer is important because it enables students to be more effective in their work and build upon previous knowledge when learning something new. Teachers need to help students make connections between what they learn in one subject or lesson and other areas. Bransford & Schwartz (1999) have studied knowledge transfer and learning. They have examined how students can transfer and apply their knowledge and skills in different contexts and situations, emphasizing the importance of bridging previous experiences with new knowledge to facilitate knowledge transfer and learning. Some examples of such bridges in knowledge transfer include actively activating and connecting previous knowledge and experiences with new knowledge or finding similarities between previously known situations and new problems, allowing students to transfer their knowledge and strategies from one context to another. Teachers can assist by making clear connections between what students have previously learned and what they will need to know in the future. Thus, knowledge transfer is about helping students develop the ability to use previously learned knowledge to learn something new. By showing them how they can apply what they already know in new situations, teachers can help students develop critical thinking skills and become more confident in their ability to learn and grow. In this case study, the concept of transfer is used in relation to learn (cf. Bransford & Schwartz, 1999; Marton, 2006).

2.2. Challenges with transfer

There are several factors that can affect transfer in learning, such as the similarity between the initial learning and the target situation, as well as the level of understanding of previous knowledge and experiences, and the interest in transferring and applying previous learning to new situations. Previous research on transfer has been subjected to critical discussion. Criticisms have been directed, for example, at the notion that transfer implies that knowledge is something that individuals "have" and can easily be moved between different contexts (Day & Goldstone, 2012). There has also been criticism of a narrow view that involves using knowledge from one situation in another similar situation (cf. for example Bransford & Schwartz, 1999; Marton, 2006). Transfer studies have been criticized for overlooking the situated nature of knowledge and treating transfer as a clearly defined action. Instead, many emphasize the importance of seeing knowledge transfer as a dynamic, continuous, and actively constructive process where the interpretation of knowledge always takes place in a new context (Kilbrink, Bjurulf, Baartman & de Bruijn, 2018).

Research has discussed what hinders transfer, and one challenge highlighted is understanding the similarities between different contexts, a phenomenon called "recognition failure", where essential knowledge is not recognized and utilized (Day & Goldstone, 2012). Similarly, research has also pointed out that recognition can hinder transfer or represent an example of "negative transfer" (Schwartz, Chase & Bransford, 2012, p. 205). Negative transfer can occur when phenomena appear to be the same and are therefore perceived in the same way, despite only superficial similarity ("Surface similarity") (Day & Goldstone, 2012).

3. METHODOLOGY

3.1. Data collection

To capture students' knowledge and examine aspects related to transfer, interviews have been conducted. Three individual interviews were conducted with students who had undergone instruction on the wastewater system over a few weeks. They worked on developing and deepening their own system model during the lessons as they acquired more knowledge. During the interviews, students were asked to think of a new technical system, draw it, and describe it. The interviews lasted approximately half an hour. The interviews can be defined as semi-structured, meaning they were open-ended but focused on specific predetermined themes (Brinkmann & Kvale, 2015). Initially, an open-ended question was asked for the students to explain and draw their own system model of any chosen technical system. The students had been taught about technical systems using a specific educational model (Engström & Svensson, 2022), which included drawing their own system model. The educational model as a whole can be seen as guidance for teaching system thinking in technology education. The educational model is composed of insightful questions that encompass a wide range of topics, for example questions about the structure, purpose and challenges of a technical system, that a teacher can ask their students and examples of activities that students can carry out. The students' drawn models, their responses, and other transcribed descriptions formed the data for this case study.

3.2. Analyze

In this case study, the Transfer theories of learning, as outlined by Day & Goldstone (2012), are utilized. This theory is relevant for this type of analysis as it focuses on capturing how students can benefit from their previous knowledge in their knowledge development. In the analysis of the empirical material, particular attention is given to what and how students relate their theoretical knowledge of the wastewater system to their description of another technical system. Two central concepts, "recognition" and "recognition failure," have been employed. The analysis involves studying and thematizing the students' drawn models and their accompanying descriptions to identify examples of transfer challenges.

4. RESULTS

The results are organized based on the analysis findings, which identified two types of transfers in the material: "recognition" and "recognition failure." Finally, these results are discussed in relation to previous research, exploring how instruction can be designed to facilitate transfer and enhance students' ability to transfer knowledge from one technical system to another.

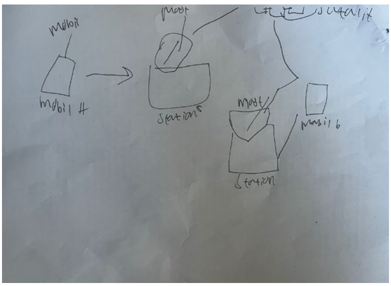
4.1. Recognition

The students describe that they can benefit from the opportunity for knowledge transfer and from having strategies to learn about another technical system.

> "I can use the questions [from the educational model used in teaching the previous system] if the systems have the same principle and can be delimited. We can take mobile communication as an example, like this, input, parts, and output. Making a model helps because it's easier to explain to others." (John)

This statement highlights the student's recognition of the value of using transfer strategies, such as identifying similarities and creating a model, to understand and explain different technical systems. It suggests that providing students with structured approaches and tools for knowledge transfer can enhance their ability to apply their previous knowledge to new contexts.

Figure 1.
John



The students also describe experiencing challenges in learning each time it is done in different ways, and that it takes time to learn the strategy, which takes away from learning the actual content.

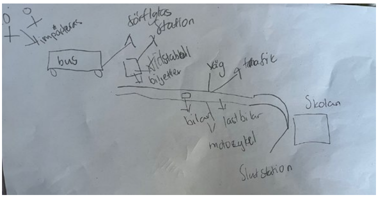
> "From my perspective, I found it easier to think about another system when I did the same thing as with the wastewater system, that is, I had the questions [from the educational model used in teaching the previous system] ready, and then it was good to draw because then I can show that it leads to that and it leads there and continues there, so I think it's much easier, and I didn't have to think about it [how to do it]" (Fredrik).

The students' descriptions demonstrate that the strategies of structure, flow, and linear thinking are transferred to their descriptions of the new technical system.

> "A transportation system is something completely different with cars and stuff, the input is people, for example, those who need to go to school, here are three roads and here is a bus, and it has different schedules. I should maybe draw the subway too, it's underground, you can compare it to the pipes in the wastewater system, and here is the school, and finally, the end station" (Anna).

These statements indicate that the students rely on their previous knowledge and the strategies they have learned, such as using questions and creating visual representations, to approach new technical systems. They also highlight the transfer of structural and linear thinking from the previous system to the new one. However, they also express the need for time and effort to learn and apply these strategies effectively, suggesting that facilitating transfer requires ongoing support and guidance from teachers.

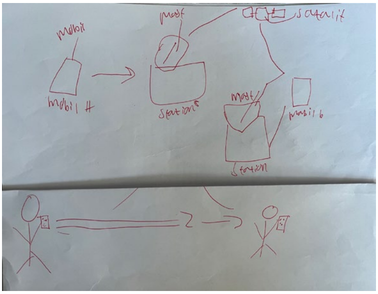
Figure 2.
Anna



The students also demonstrate flow with directional arrows in their system models, for example, showing how information flows from input to output.

> "A person talks on their mobile phone, and with the help of the internet, I think, the signal that is sent, so to speak, will be transmitted to the next person who may live on the other side of the world or maybe the neighbor. It is part of the communication system, and you understand the principle: a mobile phone, satellites, and to the other mobile phone" (John).

Figure 3.
John



However, the students don't seem to escape linear thinking, as they express how the components need to interact in the system.

4.2. Recognition failure

The students express how the subject matter differs significantly, meaning that the wastewater system is different from the transportation system, making it difficult to generalize and transfer subject content. "I can draw an input and an output, but I need to find out how the transportation system actually looks because the wastewater system is something completely different" (Anna).

However, the same student also expresses that the strategies they learned in the previous system's instruction help her systematically learn about another technical system, like "if I can learn about all systems by answering the questions and stuff, the questions [from the educational model used in the instruction of the previous system] that we did with the wastewater system."

In the students' newly drawn models, it can be observed that linear thinking is transferred as they draw components in a row, but they also mention that the components need to interact. There seems to be a belief that if you work with different technical systems, it is not possible to compare them. One student expressed, "For me, no, or I don't know, we have worked with so many different systems in a short time, and it was difficult to compare them" (Fredrik). "The first questions [from the educational model used in the instruction of the previous system] about the overall picture fit any system you want, but the last questions were in-depth questions about the wastewater system only, and it was easy to make the drawing the same." In the above quote, it becomes evident that both subject matter and principles are significant. If you have the same general questions and have practiced drawing your own system model, it is perceived that these can be used to learn about a new system.

5. DISCUSSION

The findings of the analysis have been organized into two distinct categories of transfer, namely "recognition" and "recognition failure." These outcomes are now discussed in relation to existing research, while also exploring how instructional methods can be tailored to support effective transfer and the enhancement of students' capacity to apply their knowledge across different technical systems.

5.1. Recognition

Within this category, students articulated the benefits of employing transfer strategies and structured approaches when grappling with new technical systems. For instance, John highlighted the utility of employing questions and constructing models, drawing parallels between familiar and unfamiliar systems. This acknowledgment of transfer strategies suggests that providing students with systematic tools could enhance their aptitude for adapting prior knowledge to novel contexts.

Furthermore, students mentioned challenges associated with varied learning approaches, highlighting the time and effort required to internalize these strategies. Fredrik, for instance, discussed how using a consistent approach improved his ability to tackle new systems. These anecdotes underscore the significance of consistent strategies for fostering successful transfer.

The students also demonstrated an inclination toward structural and linear thinking when interpreting new systems. Anna's description of a transportation system showcased how she employed her previous understanding to create analogies and connections between components. Evidently, there was a transfer of not only knowledge but also thinking processes from the prior system to the new one. Nevertheless, it was evident that mastering these strategies necessitated continued guidance and support, emphasizing the role of educators in facilitating transfer.

5.2. Recognition Failure

In the context of recognition failure, students acknowledged the distinct nature of subjects, exemplified by Anna's comment on the dissimilarity between wastewater and transportation systems. This divergence in subject matter posed challenges in generalizing content from one system to another. However, Anna's subsequent statement revealed that strategies acquired from previous instructions still supported her in systematically approaching new systems.

While linear thinking was observed in the models drawn by students, they also recognized the need for interaction among components. Interestingly, some students expressed a belief that comparing dissimilar technical systems might be infeasible due to their distinctiveness. Fredrik voiced this sentiment, mentioning the difficulty in drawing parallels between systems due to the rapid exposure to diverse subjects.

Nonetheless, it was evident that students found value in employing the same set of general questions and system modeling practices across different contexts. This finding suggests that transfer could be facilitated by maintaining consistent practices while allowing room for adaptations to suit the unique attributes of each technical system.

6. IN CONCLUSION

The results indicate that students exhibit both successful recognition of transfer strategies and challenges associated with recognizing transfer opportunities in varying contexts. While they demonstrate a capacity for applying prior knowledge and thinking strategies to new systems, they also encounter hurdles in generalizing these approaches across distinct subjects. These findings underscore the importance of tailored instructional methods that empower students with adaptable tools while acknowledging the nuances of different technical systems. By providing consistent strategies and guidance, educators can enhance students' ability to transfer knowledge effectively, fostering a deeper and more interconnected understanding of diverse technical domains. Consciously integrating learning transfer into education can contribute to improving students' utilization of prior knowledge and strategies and applying them in a new context. This can be relevant in areas such as education, professional practice, and lifelong learning (Barnett & Ceci, 2002). By actively promoting the transfer of prior knowledge and skills to new situations, teachers can help students leverage their existing knowledge and use it in meaningful ways. Through deliberate integration of transfer skills in teaching, educators can assist students in developing the ability to generalize and adapt their knowledge to various situations (Jensen, 2006). This concept is applicable in various domains, including education, professional practice, and lifelong learning. By teaching students to identify common principles and strategies that can be applied across different domains and problems, they can develop a more flexible and effective approach to learning. Research, such as the study referenced (Barnett & Ceci, 2002), emphasizes the importance of promoting learning transfer in education to support students' knowledge development and application of skills in different contexts. By deliberately structuring and designing instruction to include transfer exercises and reflection, students have the opportunity to integrate and apply their knowledge in a deeper and more meaningful way.

In summary, consciously integrating learning transfer in education can help students transfer and utilize their prior knowledge and strategies in new contexts. This can promote a more flexible and adaptable learning process and contribute to long-term knowledge development and application.

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Authentic Teaching in STEM Education: Factors for Success

Susanne Engström, Royal Institute of Technology, sengstro@kth.se
Helena Lennholm, Royal Institute of Technology, lennholm@kth.se

ABSTRACT

Teaching for authentic learning is described in the literature as motivating. Therefore, some schools in Sweden profile their education as authentic and some teachers strive for such teaching. During 2022, in a case study, we followed teachers and students in grade three with an age of 17-18 years, in a technology programme at a secondary school with the aim to explore specific patterns in characteristics in teaching for authentic learning. The result showed that teaching in a technology programme in an upper secondary school can be done with characteristics related to theories. Some patterns stood out as enablers of authentic teaching. Firstly, it seemed to be important to start early with authentic activities when the students begin their first year. Secondly, the teachers must let the planning, teaching and assessment "go out of control". The present work concerns a follow up study with a broader participation. Data was collected during interviews with six teachers in different schools, both primary and secondary schools. All teachers had participated in specific courses and were involved in projects dealing with teaching about space in STEM, with an authentic approach. The interviews were analysed both related to a category system based on theories about authentic learning as well as more thematic. The aim was to explore what patterns appeared as enablers of authentic teaching.

Keywords: Authentic teaching, STEM education, technology education

1. INTRODUCTION

The literature describe how teaching should be designed for authentic learning (e.g., Herrington & Oliver, 2000; 2010; Rule, 2006; Hill & Smith, 2005), with the goal of developing students' understanding of complex issues like climate change (Cross & Congreve, 2020). Authentic assignments provide a real-world context (Rule, 2006; Resnick, 1987; Young, 1993; Harley, 1993), in which students can apply their knowledge and reflect on their learning (Rule, 2006). The learning environment should be open, with opportunities for students to consult with experts (Collins et al., 1989) and encounter different perspectives. The tasks should be complex, and assessment should be integrated into activities (Herrington & Oliver, 2000). Rule (2006) describes how important it is, in authentic learning, that students, in addition to being allowed to work situationally on a real-world problem, also get to face real challenges with their task and thereby develop their thinking and acquire new knowledge. When students are taught using an authentic learning approach, they must encounter "wicked problems" (coined in Rittel & Webber, 1973) and authentic ways of working, such as group work and debating, in a way that highlights the complexity of tackling these issues (Herrington & Herrington, 2006; Pitchford et al., 2021, Lönngren, 2021, Peters & Tarpey, 2019).

The present work concerns a follow up study where we studied what emerged in teachers' descriptions of their teaching for authentic learning. The aim was to explore what patterns appeared as enablers of authentic teaching.

2. THE THEORETICAL FRAMEWORK FOR THE STUDY

In our previous work (Engström & Lennholm, 2023) we studied what characterizes teaching for authentic learning and, above all, what enables it. We chose to apply the principles of authentic learning that Herrington & Oliver (2000) and Herrington et al. (2010) have developed, presenting them as "nine guiding design elements":

(i) Provide an authentic context that reflects the way the knowledge will be used in real life,
(ii) Provide authentic tasks and activities,
(iii) Provide access to expert performances,
(iv) Provide multiple roles and perspectives,
(v) Support collaborative construction of knowledge,
(vi) Promote reflection to enable abstractions to be formed,
(vii) Promote articulation to enable tacit knowledge to be made explicit,
(viii) Provide coaching and scaffolding,
(ix) Provide for authentic assessment of learning.

What emerged in the study and appeared to be important for enabling teachers to allow students to work authentically was that teachers must dare to let go, relinquish control over the teaching, planning and assessment (Engström and Lennholm, 2023). In addition (and arguably the most crucial factor), they must have the full support of the management as well as back-up resources. The fact that the school's teaching can confidently implement the authentic method was largely explained by the management's support in respect of contacts, skills and resources, acceptance, and self-assurance.

The present follow-up study was conducted with the aim of listening to more teachers about how they work for students' authentic learning and why, as well as what enables their teaching. The same theoretical framework for what may characterize the teaching was used; the "nine guiding design elements" by Herrington & Oliver (2000) and Herrington et al. (2010).

3. METHODOLOGY

We conducted interviews with teachers with subsequent thematic analysis (Braun & Clarke, 2006). The analysis was conducted partly as a deductive thematic analysis using Herrington and Oliver's nine guiding elements, and partly as an inductive thematic analysis aimed at finding patterns in teachers' statements related to what enables authentic learning. Six natural science- and technology teachers, teaching at all levels of primary and secondary education, were individually interviewed for about an hour. The group contained both male and female teachers, all of them had a least 15 years of experience in teaching. The teachers all work at different schools, scattered across Sweden. All teachers are involved in a teacher council related to space and STEM – with an authentic approach, in which it becomes clear that they have an interest and experience in teaching for authentic learning.

The questions asked and discussed were: What examples of authentic themes have you taught? Describe what was taught and how the students worked. Can you describe how you think about such teaching? What is important and how do you assess it? What do you think is important for you to teach for authentic learning? Why do you think you do it and want to do it?

The interviews were conducted digitally and recorded. They were transcribed and analysed thematically. The aim was to find themes related to what characterises teachers' described teaching related to the nine elements, as well as what enables and otherwise characterises teachers' teaching. Before the interviews started, the teachers were informed about the purpose of the study, that it is voluntary to participate, that their names, schools, etc. will not be made visible, and that we handle recordings according to research ethics and data storage rules at our institution.

4. RESULTS

The research question was: What emerges in teachers' descriptions of their teaching for authentic learning? The different themes that emerged in the teachers' statements related to what characterize their teaching for authentic learning and what enables it. We found four themes:

- Dare to let go,
- Strong leadership,
- Need for contacts
- View on teaching in the subject.

We also present results about how the teachers' descriptions of their teaching relate to the nine guiding elements presented in Herrington & Oliver (2000) and Herrington et al. (2010).

4.1. Themes that describe teachers' teaching for authentic learning.

In teachers' descriptions and positions, four different main themes emerged related to what characterize their teaching, strategies, and personalities. For each overarching theme, different aspects that showed both similarities and differences in strategies and positions came to light.

4.1.1. Dare to let go!

This theme was evident for all teachers in the study, and they wanted to highlight the ability or personality that is important for the teaching approach to authentic learning to be possible. They recounted the importance of "daring to let go" to make authentic learning possible.

> “It's about me daring to let go”.

They outlined how the teacher needs to "dare to not know" everything and also show it to their students. When students ask questions, teachers must have the confidence to show their ignorance and their willingness to find answers together with the students. The teachers described this as "letting go," "letting go of control." It seems to be an ability that they believe sets them apart from other teachers.

> "Other teachers see it as extra work."

> "A lot of it is that the teachers are afraid to do things that you don't feel you can master yourself, instead of thinking that the children can."

Teachers emphasised the importance of being unpretentious and daring to trust oneself.

> "I don't know the answer and I have to be confident in saying it...today you get to find out the answer, it's not me who knows…then we'll find out"

4.1.2. Strong leadership

The teachers also emphasised the need for strong leadership to implement teaching for authentic learning. They reported how leadership can be described with three different meanings: the teacher's own strong leadership/mandate or that the school leadership actively supports, but also that the teacher has a soulmate, a partner who supports and collaborates.

Some teachers clarified that they themselves have power, they have obtained a mandate by being a first teacher or lecturer. They may be the one who has worked the longest, longer than the principal, and in addition, the role of subject responsibility gives them status and a strong mandate. They are listened to a lot depending on the power position they hold as a first teacher or subject responsibility, etc.

> "It has meant that I've had a lot of contacts... I'm the one they come to and ask if there's anything”.

> "I'm the kind of person who makes sure I get to do what I want."

> "I've been at my school for 25 years, so I know everyone, and everyone knows what I'm doing."

For other teachers, the importance of having the ear of the management was evident. They described that the management engages in their proposals, allowing them to implement their ideas. They can get the school management on board and obtain resources.

> "They are so open and there has been money and when we went to the technology lift, they asked if there was something we wanted."

> "We get a lot of praise both from our principals and from the administration...it feels like it's appreciated."

Another way to develop and feel strong leadership is for teachers to have a colleague at their own or another school with whom they can collaborate. It provides strength and self-confidence that can be translated into empowerment and thereby status. Teachers described how they could feel a little lonely about their approach to work in their own school but can plan and implement their ideas and thereby develop empowerment in their own school through a colleague at another school.

> "We have taken half a day during the summer holidays to co-plan. A collaboration with another person who is passionate in the same way is so developing".

> "I get some [colleagues] with me, I have a colleague at the middle school, he often takes over the students that I have had. We connect with each other".

4.1.3. Need for contacts

A prominent theme in teachers' descriptions of something that enables their teaching for authentic learning was that they create and have created contacts outside the school. One characteristic is that teachers search broadly to make study visits, to collaborate, to have meetings with different people, to make visible different actors in society. It can involve very different actors: local radio and daily press, museums and science centres, authorities and companies, politicians and experts of various kinds, universities and various industries, etc. Teachers described how, depending on what emerges in teaching, they are prepared to search widely for collaboration partners or actors outside the school.

> "Then X, my colleague and I discussed, how are we going to get this project out... then we started talking about the local radio and then we contacted them."

However, some teachers clearly take a position on who and with whom to collaborate. For example, private companies were considered not to have a place in schools. In such cases, there are criteria for who to contact. Universities, government agencies, and municipalities were considered suitable. The argument was that private companies should not have an impact on schools.

> "I would like to have contact with a research institute, but I don't think we should involve private companies in the school. It is more of a matter of principle".

On the other hand, other teachers emphasised entrepreneurial skills as fundamental and believe that it is rewarding for students to encounter private initiatives and both small and large companies. Such encounters can serve as inspiration. Similarly, these teachers believed that local businesses could contribute to schoolwork, including being a future employer for students.

> "I think that the part that is still in our curriculum that you should try to work with companies around you is really neglected in school."

> "It also usually creates some interest for the students because it is slightly more in reality."

A dividing line can thus be discerned in terms of whether teaching for authentic learning should involve private companies or not.

4.1.4. View on teaching in the subject

In the teachers' descriptions and positions, a clear view of teaching in general and in specific subjects emerged. We chose to interview teachers who teach technology and other STEM subjects; and they mainly talk about such teaching. A theme that was strongly expressed is the strong desire to include all students. By "doing something active," investigating something, looking at something in reality, "going out and looking," teachers succeed in capturing everyone's attention. Which is not considered possible in the classroom with sedentary activities linked to textbooks. Going out and meeting reality provides explanations through experiences with multiple senses. Teachers outlined how they can have difficulty explaining certain things to students who have not experienced what is being discussed. Going out and looking, making a study visit, touching, and investigating, talking to different actors becomes for some students the only way to understand. It helps many students who have a different first language and may have come to Sweden recently. Teachers also described how students with different diagnoses and disabilities also benefit from activities in and collaborations with "reality", and expressed how important it is for them to bring all students with them all the time and believe that it should guide their teaching.

> "In order for them to understand, it is important to be able to show as many (ways) as possible, when we talk about a moving block, we have to go out and look at a moving block so that they understand."

> "Students think it's fun when there are practical things too, not just sitting in their chair but you get to do something."

> "I've got a blind student...very interesting to do experiments so that he can take part in it."

Another subtheme that emerged was that teachers always want to listen to students and start from their questions and interests. The questions students ask became the starting point for what is taken up in teaching and guide how teaching should be designed.

> "The important thing is that you arouse their interests and that they find it fun."

> "I have a plan, but my planning is shaken up based on the students' questions and interest."

> "I try to connect as much as I can with students' reality, our reality, so that it becomes something meaningful."

Another related subtheme that appeared in the teachers' reasoning was that students must "understand life." They described how life exists outside of school and the classroom and that students need to develop knowledge and abilities in "life" to understand it better. Among the studied teachers, there was a clear view that should take place in reality, linked to life's tasks, and that these should be understood. It can be about understanding technical systems, building development, energy supply, ecosystem services, chemical processes, etc. according to teachers, most things can be learned in contexts outside of school.

> "They have to understand how things are in society, we can't have garbage mountains, they have to make things better."

The teachers in the study talked about an "unconventional culture", that they are distinct teachers who do not think like others, that they look at their subjects differently than many others do. They highlight their difference from other colleagues or many of the teachers who are newly graduated. Teachers believe that they have developed a different view of their teaching and their subjects over many years. Overall, teachers want to explain their teaching for authentic learning with their different view.

> "I think I'm the kind of impulsive person who gets a lot of ideas and then I just do it…often it's fun too and then you get energised."

4.2. Aspects related to "nine guiding design elements"

In the teachers' descriptions of the authentic themes, they work with or have worked with, we could see that they cover many different areas, such as water purification, urban planning, personal care products, technical systems in the city, space-related technology, and so on. The aim highlighted was for students to be in an authentic context that gives them the opportunity to experience how knowledge is used in real life. They should also receive questions and assignments that are real. The themes applied well to Herrington & Oliver (2000), except for no (iii); Provide access to expert performances, that was less apparent in the interviews. The teachers communicated and collaborated with the expert, but students more seldom get to work with people outside of school. The projects set out by teachers may involve field trips in which a person, a role, tells the students about what they do and how they work. The students do more seldom directly collaborate and work in this context. However, students were given the opportunity to collaborate with each other and thus construct knowledge together. They receive guidance from the teacher and are given the opportunity to reflect. In some projects, students were also allowed to present their results to an authentic user.

5. DISCUSSION

This study focuses on how teachers who consider themselves to work authentically describe their teaching, and we have interpreted what characterizes the teachers, their teaching, and what seems to enable teaching for authentic learning.

The themes that emerged: Dare to let go, Strong leadership, Need for contacts and View on teaching in the subject, include teachers' views of themselves and their teaching, which seem to revolve around personality, beliefs, commitment, and strengths of the individual teacher, and thus different strategies that are made possible. We observed how all teachers consider the authentic project and approach to be central in teaching, with the curriculum being somewhat squeezed in. Although they do follow the curriculum, the authentic approach takes precedence. At the same time, the teachers described often feeling alone in their role and their approach to teaching. Colleagues may express scepticism, concerns about losing control, or believe that the approach is demanding. The teachers also expressed how newly graduated teachers may find it challenging to embrace authentic teaching. Possibly, teacher education programs are influenced by a logic that does not directly encourage prospective teachers to develop the perspectives and attitudes that characterise authentic teaching.

In essence, all nine guiding elements highlighted by Herrington and Oliver (2000; 2010) as characteristics of authentic learning instruction emerged in the teachers' descriptions of teaching examples. They allowed students to experience authentic learning to a great extent, encountering real problems and challenges, collaborating with each other, visiting real environments, and carrying out real tasks. Their teachers acted as guides who also allow students to seek and find knowledge from other sources, etc.

What did not seem to be fully enabled was students' opportunity to truly collaborate with actors outside of school. The teachers took the contacts, and the students did encounter individuals with specific roles outside of school, primarily during field trips or for occasional meetings (such as a presentation or other specific tasks). However, there were no concrete collaborations or consultations, discussions, etc., with actors outside of school for the students.

Although students did encounter real problems and tasks, which according to the teachers enable authentic learning (as described by Herrington & Oliver, 2000; Rule, 2006), the teachers attempt to guide them in addressing the complexity of the problems (an important aspect of authentic teaching according to Peters & Tarpey, 2019). Many teaching examples featured problems related to major societal challenges of our time (emphasized by Cross & Congreve, 2020), but when students did not interact with different actors and interest groups in their concrete work, when they were not challenged in discussions by actors outside of school, they may have difficulty fully grasping the complexity and challenges of the tasks they are working on (the importance of discussing and being challenged regarding complex problems is emphasized by Herrington & Herrington, 2006; Pitchford et al., 2021). The tasks, activities, and examples risk remaining school assignments with an authentic touch rather than authentic work. However, it is likely very difficult for schools and teachers to establish concrete and real collaborations with actors outside of school. Both teachers and actors probably do not have the time. For many actors, it is likely difficult to find the time and value being a collaboration part and actively participating in students' work.

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Approaches to industrial processes in technology textbooks

Susanne Engström, Royal Institute of Technology, sengstro@kth.se
Pernilla Sundqvist, Mälardalen University, pernilla.sundqvist@mdu.se
Charlotta Nordlöf, Linköping University, charlotta.nordlof@liu.se
Claes Klasander, Linköping University, claes.klasander@liu.se

7. ABSTRACT

The aim of this study is to explore how technology textbooks can provide students with a basis for expressing knowledge about technical solutions within industrial processes. The base and the delimitation for the study is the formulation of the specific content on industrial processes that must be taught to 13 to 15-year-olds in Swedish schools pursuant to the national syllabus. Textbooks constitute an important foundation for teaching, particularly in the subject of technology, in which teachers may find the breadth of content they are expected to teach challenging. The study analyses the sections concerning industrial processes in four different technology textbooks commonly used for students in the age group 13–15. Analysis involved interpreting content in the form of text, images, assignments etc. related to aspects that are expected to characterise students' descriptions and explanations of technical solutions: understanding of technical solutions purpose and functionality, how components interact as a whole, similarities to other technical solutions and relating them to their own experiences. The results show that these aspects emerge in different ways depending on, among other things, how the area is presented. We found three different ways in which industrial processes are presented in the textbooks: A unique industrial process is described carefully and in detail, Sub-processes and methods are presented systematically and Industrial processes are described as technological systems at a general level. One interpretation is that, as a teacher, you can teach about industrial processes in these different ways and that which one you choose affects to what extent certain aspects of technical solutions are visualised for the students.

Keywords: technology education, technical solutions, textbook analysis, industrial processes

1. INTRODUCTION

In Sweden, the intention in primary school is to increase the use of textbooks. A state public inquiry (SOU 2021:70) concluded that students need textbooks in all subjects to fully acquire knowledge and develop competencies. In the case of the technology subject, according to the curriculum, students should be able to describe, explain, and reason to demonstrate various aspects such as breadth and depth, how they base their understanding on facts or personal experiences, their perception of purpose and functionality, etc. (Swedish National Agency for Education, 2022a). This enables the assessment of students' knowledge and competencies. Textbooks are produced, for example, due to changes in syllabi or because teachers or students express a need for textbooks in a subject. The proposal may also come from a textbook author who has an idea for a new textbook (SOU 2021:70).

Well-functioning textbooks are a key factor in students' academic results (Oates, 2014), including in STEM-education (Chiappetta & Fillman, 2007; Kahveci, 2010). They also provide support for teachers in planning and organising their teaching (Lindensjö & Lundgren, 2000; Oates, 2014). Furthermore, textbooks can offer content support for teachers who may be uncertain about their subject knowledge (Englund, 2006). This is particularly relevant for teachers who are not qualified in the subjects they teach, which is prevalent in Sweden, especially for the technology subject.

In this project, we analyse four technology textbooks with the aim of investigating how their content can provide students with a foundation for describing technical solutions, especially industrial processes. With industrial processes we mean large scale industrial manufacturing processes. We aim to identify characteristics and patterns in the textbooks regarding this aspect.

2. LITERATURE REVIEW

There are several reasons to use a textbook. One reason is to provide structure in teaching. There should be a clear progression between different knowledge areas and abilities. Students should encounter gradually more challenging tasks and texts to promote their knowledge development (Fan et al., 2013). Each textbook incorporates pedagogical and didactic considerations, and the design of the texts in the textbook constitutes "a selection and a specific organization of knowledge for learning" (Lindensjö & Lundgren, 2000, p. 16). Textbooks greatly influence learners' understanding of a subject by shaping the strategies teachers use in the classroom and the order of instruction (Chiappetta & Fillman, 2007; DiGiuseppe, 2014; Stern & Roseman, 2004), and influence learning outcomes by presenting the content that students should learn and promoting the skills and abilities they should acquire through that content (Valverde et al., 2002). Textbooks are often used to enable absent students to catch up and are valuable resources for exam preparation (Englund, 2006). Additionally, textbooks can be seen as documentation of students' progress when they are sent home to parents (Korsell, 2007). Furthermore, textbooks are often a source of facts and examples with breadth and depth. Students utilize the content of the textbook to describe subject matter based on facts and provide examples (Andersson-Bakken et al., 2020).

Textbooks thus play a significant role in students' learning. In the context of technology education in Sweden, students should be given the opportunity to "develop knowledge about technical solutions and how components interact to achieve purpose and functionality" (Swedish National Agency for Education, 2022b, Lgr22). This raises questions about what should be considered knowledge and what is deemed important to include or exclude from the curriculum and the teaching (Deng & Luke, 2008). The knowledge that emerges in textbooks and how it is presented thus becomes an interesting question. Deng and Luke (2008) provide three "conceptions of knowledge" derived from different knowledge classification schemes, which we use when discussing what occurs in technology textbooks for students aged 13–15. The first knowledge distinction they describe is called a *disciplinary conception of knowledge*. This knowledge is characterized by placing ideas, concepts, methods, processes, and facts linked to a specific academic discipline in the foreground. The second "conception of knowledge" is the *practical conception of knowledge*, which "construes knowledge in terms of knowing what to do in practices and actions, with an emphasis on the application of knowledge to practical and sociocultural problems" (Deng & Luke, 2008). Such knowledge can range from embodied knowledge, for example, riding a bicycle, to more explicitly cognitive activities such as writing computer programs. Deng and Luke argue that this constitutes and requires procedural knowledge. Practical knowledge cannot be reduced to simply knowing a set of procedures or skills; it involves making thoughtful choices and actions based on deliberate decisions. The third conception is an *experiential conception of knowledge*. Instead of viewing knowledge as something separate from humans, as the first disciplinary conception does, this experiential conception "locates knowledge in the realm of ordinary human experience" (Deng & Luke, 2008). Knowledge is a process in terms of an ongoing construction of meaning between an actor and their environment and other actors (Deng & Luke, 2008).

In the four textbooks, we limit the analysis to the central content referring to the area of Technical Solutions in the syllabus for the lower secondary school : "Processing of raw materials into finished products and handling of waste in an industrial process, for example in the production of food and packaging" (Swedish National Agency for Education, 2022b, Lgr22). We call the content *Industrial Processes* and the knowledge goal can then be expressed (our own formulation based on knowledge requirements and goals): knowledge of industrial processes and how components collaborate to achieve purpose and functionality. The aim is to obtain an understanding of what knowledge textbooks offer to students regarding industrial processes. The research question is: what is prominent in the textbooks' texts and images related to industrial processes?

3. METHOD

The data sources for this study are four textbooks in Technology education for pupils aged 13-15 years. In each textbook the pages concerning *Industrial Processes* were chosen: book 1 (20 pages), book 2 (35 pages), book 3 (34 pages) and book 4 (14 pages) respectively. These pages were read thoroughly by the four researchers, however each of us was responsible for the identification of significant units for analysis, choosing quotes and pictures/illustrations and summarising the initial impressions in relation to the aim for the study. The content in the books was also compiled from the aspect of how it could contribute to pupils' use of the content when describing industrial processes (1) by showing understanding for purpose and functionality, (2) generalising by highlighting similarities with other technological solutions, (3) how parts and sub-processes cooperate as a whole and (4) by relating to personal experiences. These four aspects of describing technology are based on advisory documentation where The Swedish NAE comments on the curriculum (Swedish National Agency for Education, 2022b, Lgr22). From this point a thematic analysis (Braun & Clarke, 2006) was made by the whole research group aiming at finding emerging patterns that could answer our research question.

Thereby, the thematic analysis of the content of the textbooks was first carried out with the aim of identifying sub-themes within the content in the four aspects mentioned above, and then to see patterns in how the content is presented. This means that for each aspect of the content in the textbooks, a number of themes emerged. Then, the themes concerning how the content is presented were interpreted jointly by the four researchers.

4. RESULTS

Under each theme, we qualitatively describe what has emerged in the analysis, i.e., the different ways in which the theme is addressed in the textbooks. A book may address a theme to a greater or lesser extent. We have not analysed to what extent each book addresses each theme or sub-theme.

4.1. Characteristics of the content

4.1.1. Purpose and functionality

The purpose of technical solutions and what they do is described. The described purpose can be more or less clear, and what the technical solutions do and how they work is described in more or less detail. For example, the purpose of industrial processes is described as an economical and efficient way to produce goods, or that a machine cuts pipes in suitable lengths in the production of wheelbarrows.

The functionality of different technical solutions is compared based on what is to be achieved. For instance, pneumatics, hydraulics and the servo motor are described in different processes and are put in relation to each other. For example, "How do you move something a short distance? And maybe in very small steps? For this pneumatics do not work so well because it is not so easy to get a cylinder to stop in small steps. For such movements, an electric servo motor can be used". This shows how the functionality of the electric servo motor is better than pneumatics for the purpose of moving something a very short distance.

Functionality is described from the historical development in terms of economic efficiency and an environmental perspective. For instance, it is described that Henry Ford developed the assembly line to make production more effective, and the development of filters in chimneys to prevent pollution.

Functionality is taken for granted. An uncritical and positive view of technology is discerned where the technical solution is portrayed as the obvious one. Thus, functionality is not mentioned.

4.1.2. Generalising by highlighting similarities with other technical solutions

A general description of process industry is given – more or less detailed, followed by examples that enable generalization on various levels.

Generalization of process industry. The understanding of what a process industry is facilitates by providing several examples, such as paper mills, dairy factories, and steel mills. Through both the brief description of what a process industry is and these examples, students can begin to understand process industries on a general level.

Generalization of technical solutions within process industry. Two approaches were identified. The first approach starts the description of the manufacturing process in the details, for example the process of producing a wheelbarrow, with its principles and methods. In the following it is explained that several of these methods are also used in other manufacturing processes. The second approach departs in the methods and sub-processes, such as mechanical processes and chemical processes, joining methods, and forming methods. These are described, and examples of where they occur are given, e.g. “some examples of mechanical processes are when wood is chipped in the production of pulp, when coffee beans are grained in a mill and when olives are pressed to olive oil with a press machine.”

No enabling for generalization. Technical solutions are described solely through the process that serves as an example. No comparisons or connections are made to other processes or solutions that use the same principles or methods, therefor the text doesn’t support the students in transforming the knowledge to other examples of processes.

4.1.3. How parts and sub-processes collaborate as a whole

The collaborating parts are described at a system level. Collaboration is demonstrated between the different sub-processes. A clear overview of the process is provided, with several examples. An overall system level is in focus. For example, a dairy is described as a technological system, both in text and visualised by a model.

The collaborating parts are described in detail. Collaboration is demonstrated between the parts within the sub-processes. One example is given, such as the production of milk powder, and it is described in detail by text and photos. However, an overview of the entire process is missing, which can contribute to difficulties in seeing whole.

4.1.4. Relate to personal experiences

Using examples most students have experience of. This can be the production of potato chips or toothbrushes – products the students are familiar with and commonly use.

Using analogies. Difficult processes are linked to something the students are familiar with. An example is a description of how milk powder is produced. Here, the separator is described to spin “like a roller coaster” and the evaporation of the water in the milk “happens in a saucepan, tall as a tower”.

Giving experiences to relate to. The students are given experiences, through exercises, which they can use to discuss the industrial process. An example is the production of paper. In the chapter that describes how paper is produced in the paper mill, an exercise for making pulp and paper from used newspapers is included, and the students should compare this to the production in the paper mill they have read about.

4.2. Characteristics for how the content is presented

4.2.1. One unique industrial process is described carefully and in detail

Industrial processes are described with one unique example, which is presented carefully and in detail. Steps and methods in sub-processes are thoroughly explained to contribute to knowledge about the specific process, what the different methods of that process aim to achieve, and how the technical solutions work. No overall picture is provided, which makes it difficult to see the big picture.

4.2.2. Sub-processes and methods are presented systematically

Industrial processes are described based on different categories to show that industrial processes can look different and be divided into different groups with common denominators, such as chemical processes and mechanical processes. Sub-processes and methods are also systematized and categorized to show similarities and differences. Both processes and sub-processes are described at a more general level rather than in detail.

4.2.3. Industrial processes are described as technical systems at a general level

The presentation of the industrial process as a technical system can be more or less comprehensive, from a general description of the process showing how the parts are interconnected as a system, to the industrial process being an example of a technological system, meaning that the industrial process is used as a way to develop an understanding of what a technical system is. In the latter case, the technical systems' terminology is used to describe the parts of industrial processes – sub-processes are referred to as components, the system boundary is defined, how the system interacts with the environment etc.

5. DISCUSSION

In the results of the textbook analysis, both the characteristics of the content and the way it is presented are identified. Relating the characteristics of the content to Deng and Luke's (2008) conceptions of knowledge, we see the presence of two out of three conceptions of knowledge. The content is highly characterized by a disciplinary conception of knowledge. Processes and methods are described theoretically in the presentations. Students are given the opportunity to develop theoretical knowledge through facts and descriptions about the technical solutions in industrial processes. In some books, an even more theoretical image is presented where attempts are made to systematize different methods and processes or describe them as general technological systems. Regarding the experiential conception of knowledge, industrial processes are probably something many students have little, if any, experiential knowledge about. Thus, relating to own experiences might be difficult with this content. However, several attempts are made in the textbooks, for example in assignments where students are asked to do something of a more practical character, e.g., to construct a model of an assembly line and program it based on an Arduino platform and relate it to what they have read in the book about industrial processes. They also do so by relating the theoretical content to experiences and knowledge the students are assumed to have. However, even though students are given practical tasks, the practical conception of knowledge (Deng & Luke, 2008) is completely absent. The tasks have nothing to do with the actual industrial processes, the content becomes something else, moving away from industrial processes as the main focus.

Regarding how the content is presented, we have identified three different approaches in the analysis:

Firstly, by focusing on how one unique industrial process is described carefully and in detail the students' experiences presentations of sub-processes where the main construction materials are handled, refined and moved to next sub-process for further refinement and assembly the risk is that the overarching aims, methods and flows are omitted. The concepts, ideas, processes and facts Deng and Luke speaks of is thereby to high extent connected to the particular example, not the general.

In contrast - when processes, sub-processes and methods are presented systematically - understanding of concepts, ideas, processes and facts (Deng & Luke, 2008) is general and not related to one example in particular. In this approach the focus is on giving the students an overall understanding of industrial processes and students learn about ways to categorize industrial processes and methods. The students will be able to describe industrial processes at an overall level but lack deep knowledge to understand one specific process in detail. The students will have knowledge about similarities and differences of industrial processes, but at an overall level, for example knowing industrial processes as chemical or mechanical. One risk in this approach is that students don't understand the complexity of each single process. On the other hand, students will be able to see common denominators, even though the products produced are of completely different characteristics.

In the third approach the concept, ideas, facts, processes etc. are more rooted in a tradition of systems thinking (Barak & Williams, 2007; Checkland, 1981; O'Connor & McDermott, 1997) which values an understanding from perspectives where the systems delimitation towards an environment, its inputs, outputs and flows are central in the presentation for the students. Process diagrams are sometimes used as a support in this approach. This has obvious benefits on an analytical level in textbooks but might need more thoroughly presented examples from authentic industrial processes to make the interdependence between the disciplinary perspective and the practical perspective (Deng & Luke, 2008) clearer to the students.

We note that, regarding all the three approaches, the analyzed textbooks do not seem to have coherent views on which examples (black boxes) at different levels to keep closed and which to unpack for the students, not within a textbook or between them.

One interpretation is that as a teacher, you can teach about industrial processes in these different ways. By making them explicit technology teachers can reflect on how they want to teach, as the approach they choose can affect what they can make visible regarding the technical solutions of industrial processes.

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Fostering Creativity through Design and Technology Education

Robert Farrugia, University of Malta, robert.farrugia.06@um.edu.mt
Inġ Lawrence Farrugia Caruana, University of Malta, lawrence.farrugia@um.edu.mt
Sarah Pule, University of Malta, sarah.pule@um.edu.mt

ABSTRACT

The challenges faced by contemporary societies, together with the on-going change characterizing these societies, reveal the need for citizens who are able to think differently and adapt what is already known to new, unknown situations (Cropley, A., 2011). This ensures that change is pro-actively managed. Education plays an important role in supporting active citizenship (Apple, 2013), where a methodology that promotes creativity ensures the effectiveness of pluralism in democratic societies. Teachers, however, are faced with dilemmas, having to compromise between the requirements for creativity and the demands of education systems (Atkinson, 2000; Runco, 2014a). Design and Technology Education has a potential role in addressing these dilemmas, due to the authenticity afforded and the potential of design practice to foster the metacognition required for creativity (Christiaans & Venselaar, 2005). This paper presents the research conducted to build a toolkit for secondary school Design and Technology Educators, intended to capitalize on this potential. It was developed following an exploration process aimed at identifying a pedagogy that facilitates the fostering of creative mindsets through the subject. This process consisted of interviews with Design and Technology teachers to understand creativity in the local classroom, in addition to a literature review. The toolkit was then evaluated through interviews with other Design and Technology teachers. The underlying philosophy of the toolkit is based on the 4P framework (Rhodes, 1961) – Person, Process, Product, and Press – to address creativity holistically, with the creative Person as its long-term goal. This is embodied through the design process at the core of the toolkit, facilitated using the spiral curriculum (Bruner, 1977) and specific design tools. The evaluation of the toolkit shows that it can support high-level thinking required for creativity, confirming the role of Design and Technology Education in preparing present and future generations for the society they design and live in.

Keywords: Creativity, Design and Technology, Toolkit, Teaching resources.

1. INTRODUCTION

In the face of long-term challenges, and on-going change such as the realities of climate change and industry 4.0, contemporary societies require citizens who are able to think differently and adapt what is already known to new, unknown situations (Cropley, A., 2011; Cropley, A., 2020). Education plays a role in supporting active citizenship (Apple, 2013) through a "problem-posing" methodology based on creativity (Freire, 1993).

Teachers, however, have to compromise between the requirements for creativity and the demands of education systems (Atkinson, 2000; Runco, 2014a). Design and Technology (D&T) Education can potentially address these dilemmas, due to the authenticity afforded and the potential of design practice to foster the metacognition required for creativity (Christiaans & Venselaar, 2005). Keirl (2008), points out how besides material objects humans also 'design' society, culture, and political systems amongst others.

This paper mainly describes the research conducted to inform and develop a Toolkit (unpublished) for secondary school D&T teachers to help them foster creativity amongst students aged eleven to sixteen. The guiding research question is the following:

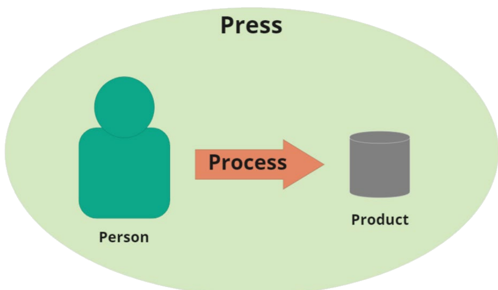
How can D&T teachers make lessons more conducive to creativity?

2. LITERATURE REVIEW

2.1. Defining Creativity

While there is no straight forward definition for 'creativity' (Fisher, 2004, p.7; NACCCE, 1999), Rhodes' (1961) framework categorising creativity under four inter-related themes helps clarify the scope covered in this study. These themes are: Product, Process, Press, and Person, (Figure 1) referred to as the 4Ps of creativity (Rhodes, 1961). In this study it is being used to define the facets of creativity that will be explored.

Figure 4.
The relationship amongst the 4Ps (Adapted from Hyun-Kyung & Soojin, 2015, Figure 1)



2.2. Creativity in Education

The role of schooling in creativity has not always been interpreted as positive. The need to conform suppresses children's natural creativity (Kelley & Kelley, 2013; Robinson, 2006). When trying to teach for creativity, teachers are often faced with a dilemma from pressures to plan and be accountable (Runco, 2014b).

One question that needs to be asked is whether creativity can be taught. Some believe that creativity emerges spontaneously if not blocked (Cropley, A., 2011; Runco, 2014b). Others believe it can be enhanced through training and explicit instructions (Cropley, A., 2011; Tran et al., 2020). It can then be concluded that the role of education is twofold: the removal of barriers to creativity followed by explicit teaching.

2.3. Creativity in Design and Technology

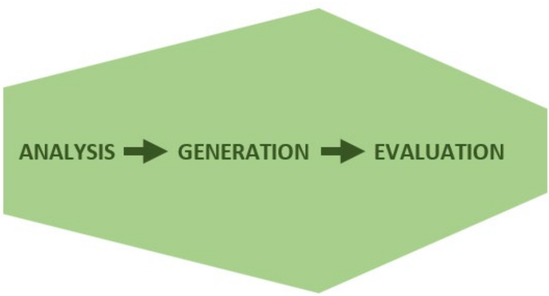
Design-based learning is a tool that brings real-life problem-solving methods into the classroom. The ill-defined nature of design problems (Cross, 2006; Kimbell & Perry, 2001), allows room for multiple solutions and hence for creativity (Bozkurt Altan & Tan, 2021; Cropley, D. & Cropley, 2010; Lewis, 2005). Furthermore, Howard et al. (2008) highlight the links between creativity and design and how the 4Ps of creativity appear in design.

2.3.1. Process

Process is concerned with the thinking processes to achieve a creative outcome, and hence can include definitions of creativity as 'Problem Finding' and 'Problem Solving' (Cropley, D. & Cropley, 2010; Lille & Romero, 2017; Runco, 2014b).

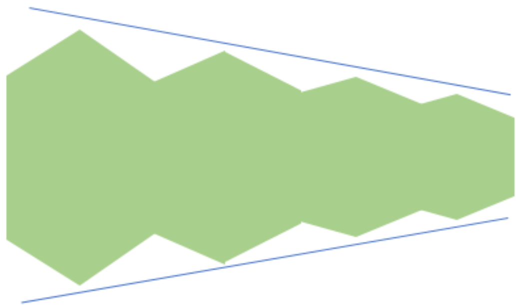
Comparative studies by Howard et al. (2008) and Warr & O'Neill (2005), later revised by Hyun-Kyung & Soojin (2015), synthesize multiple creative process models under three common stages which can be presented as a divergent-thinking phase followed by a convergent-thinking phase (Figure 5).

Figure 5.
The Creative Process



The study by Howard et al. (2008), like other authors (Brown, 2009; Fernandez et al., 2002; Thoring & Mueller, 2011), further describes the design process as a sequence of iterations of the creative process, contained within a gradually narrowing possibility space (Figure 3).

Figure 6.
The design process as an iteration of divergent-convergent creative processes within a narrowing possibility space



Hubka & Eder (1996) describe the design process as transformative: while students learn to design, they also learn through design. Christiaans & Venselaar (2005) explain that general process knowledge, acquired through frequent practice of the design process is correlated with improved creativity resulting from improved metacognition.

2.3.2. Product

From a psychology perspective, the creative output is an idea, while from an engineering design perspective, output refers to a finished product (Howard et al., 2008). In the educational setting, while students should be assisted to reach a finished product, ideally educators recognise and promote creative ideas, even when students are not able to translate them into finished products. Additionally, various authors discuss how a creative product is not just unique but also appropriate, relevant, and of value (Amabile, 1983; Cropley, D. & Cropley, 2010; Denson et al., 2015; Robinson, 2017).

2.3.3. Press

Rhodes (1961) defined Press as the interaction between humans and their environment, which can have positive or negative effects on creative performance. From an educational perspective, parallels can be drawn between Press and constructivist perspectives of education, particularly Vygotsky's socio-cultural perspective. In the D&T classroom, Barlex (2004) considers the design-and-make assignments as the instruments for creativity, allowing teachers to present relevant contexts.

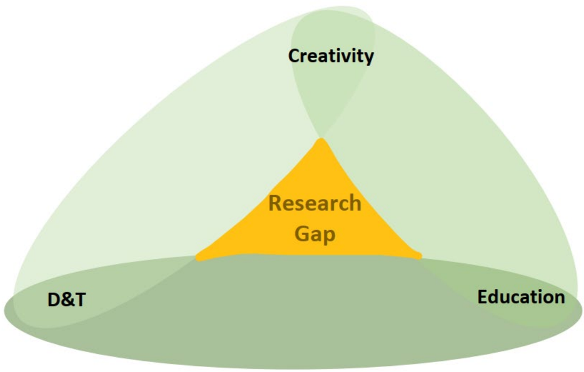
2.3.4. Person

Person refers to the personal attributes and qualities of the creative individual. Cropley (2011) refers to a "constellation of psychological characteristics" (p. 436), while Runco (2014b) explains how emotional barriers can result from risk avoidance, fear of mistakes and ambiguity, and lack of confidence. Risk taking is considered a fundamental requirement for creativity by Barlex (2004) and Thoring & Mueller (2011).

2.4. Research Gap identification

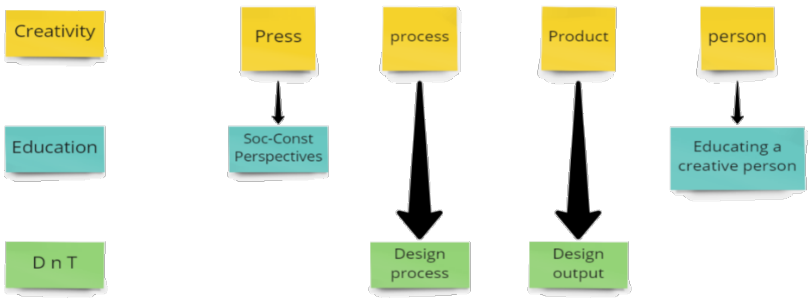
The multitude of factors that need to be considered to promote creativity, as identified in this review, mean that teaching for creativity is a complex task for teachers. It therefore seems reasonable that teachers need support to meaningfully foster creativity. This study is concerned with a triad of fields of study: D&T, Education, and Creativity. Most of the literature reviewed addresses a combination of only two of these three fields. Even literature which addressed the three of them (i.e., Creativity in D&T Education) tends to focus on a small selection of the factors discussed. This is also true for the toolkits reviewed.

Figure 7.
Research Gap identification



This highlights a gap in the existence of holistic guidance for teachers incorporating factors from the three major fields which can be directly employed in the classroom (Figure 4). In view of this, this research aims to address this gap by applying the knowledge acquired in this study to develop a holistic toolkit addressing teachers' needs to foster creativity through D&T education (Figure 5).

Figure 8.
A broad mapping of the knowledge from the three fields being addressed, forming the basis of the proposed solution.

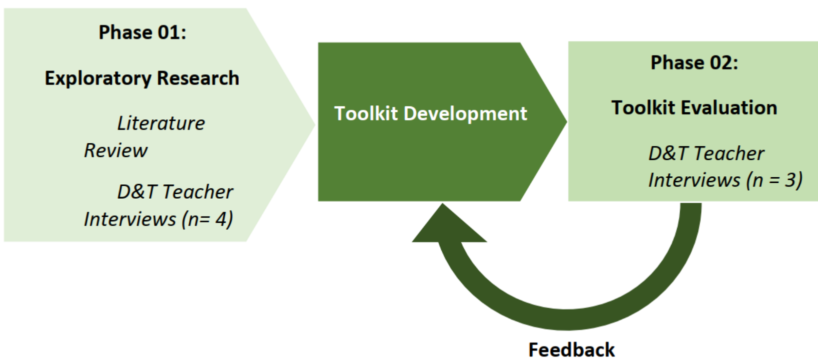


3. METHODOLOGY

3.1. Research Approach

The research process was organised in two phases (Figure 6):

Figure 9.
Organisation of the research process



3.1.1. Phase 01 – Exploratory Research

This was aimed at gathering data through the literature review, and four interviews with practising Maltese secondary school D&T educators to address the main research question. The findings from this phase were analysed inductively and translated into the development of the toolkit.

3.1.2. Phase 02 – Toolkit Evaluation

Further interviews were carried out with three D&T teachers who, based on their experience, reviewed the first version of the toolkit to assess its potential to foster creativity in D&T classes. This served as a feedback loop into the design process and, where possible, aided the improvement of the second version.

3.2. Research Methodology

A qualitative research methodology was adopted, based on constructivist theories whereby people construct meaning to interpret the world around them (Cohen et al., 2018). It was deemed appropriate since the main aim of the study was the creation of a toolkit for teachers, therefore understanding their views and needs, helped ensure the toolkit addresses their realities. Both phases make use of one-to-one, standardised, and structured interviews using open-ended questions for data collection. Questions for Phase 1 were aimed to identify teachers' definition of creativity, its role in D&T, ways students demonstrate creativity in the subject, and challenges and strategies to promote creativity. Questions in Phase 2 investigated practicality of the toolkit in the classroom, including strengths and limitations they could identify.

3.3. Sampling and recruitment

The snowball technique was used for recruitment of participants, using their social networks and contacts, to gain access to other participants. The community of D&T teachers in Malta is relatively small and close-knit, hence this technique increased the probability that a participating teacher encouraged a colleague to participate.

3.4. Data analysis

Each interview was audio-recorded, transcribed, and anonymized in preparation for the data analysis. Thematic analysis was used, following the steps recommended by Braun & Clarke (2006), and Creswell & Creswell (2018).

4. FINDINGS AND DISCUSSION

4.1. Phase 1: Exploratory Study

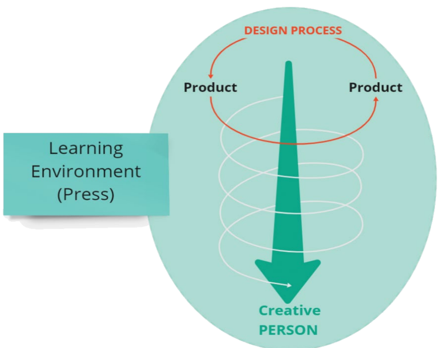
4.1.1. Defining Creativity and its links with D&T

Initial attempts by participants to define creativity expressed the elusiveness and fuzziness expressed in literature (Fisher, 2004; NACCCE, 1999). Further attempts were related to the creative Product, especially in linking creativity with D&T. Also, while participants seemed to know the core qualities that make the subject suitable for promoting creativity, they did not express these qualities when asked directly.

To raise awareness about a holistic view of creativity, and links with D&T, the toolkit includes the following:

- A philosophy that addresses all 4Ps (Figure 7).
- Placing the design process as presented in the D&T syllabus (MATSEC, n.d., Table J), at the backbone of the toolkit design. It focuses on the first two phases (Exploration and Designing) since design freedom beyond these phases is significantly reduced (Fernandez et al., 2002).
- Using the spiral curriculum, integrating different topics within frequent practice of the design process.
- Authentic tools used in real-life design, encouraging exploration of real-life scenarios.

Figure 10.
A graphical representation of the underlying philosophy for the toolkit, integrating the 4Ps of creativity.



4.1.2. Factors affecting Creativity

The most prominent factors affecting students' creativity as discussed by participants were the following:

- Barriers:
    - Students' inability or lack of confidence in expressing themselves, reflecting findings in a project discussed by Barlex (2007) where students come up with more creative ideas when they knew that they did not need to make the product they were designing.
    - Creativity or design fixation, also highlighted by Barlex (2004) and Cross (2006)
- Facilitators:
    - An opportunity for students to have sensory interaction with their ideas. This mirrors the benefits of modelling and prototyping described by Pahl et al. (2007) and Thoring & Mueller (2011).
    - A learning environment and classroom climate which promote freedom, autonomy, fun and enthusiasm where students feel safe and confident to express their ideas – relatable to the 'Press' aspect of creativity (Rhodes, 1961)

These findings are incorporated in the toolkit by including:

- A section with tools addressing aesthetic and functional expression and interaction.
- Tools titled 'Parallel prototyping' and 'Flexible Modelling'.
- An 'Energizers' section for the short-term, and 'Tools for a Creative Environment' for the long-term fostering of a creative learning environment.
- Tools instigating breaking out of an initial 'frame of reference' (Akin and Akin, 1996, as cited in Cross, 2006): Reverse Brainstorming, Dark horse, Random word, and Brain writing amongst others.

4.1.3. Methods to promote creativity

The main methods used by teachers, include:

- Providing external stimuli at an ideal timing similar to findings by Zhao et al. (2021).
- Collaborative learning.

Since the methods employed varied with different teachers, it was felt that the toolkit should promote these methods to ensure all students receive homogenous education. Additionally, some methods were inspirational to the creation of the toolkit. Based on these methods, the toolkit includes the following:

- The design process as the backbone of the toolkit and the recommendation to practice this frequently to foster creative confidence (Balakrishnan, 2021; Panke, 2019);
- A recommendation that for scaffolding purposes, students are first introduced to the design process using case studies and product analysis. When gaining experience they are provided more open-ended scenarios (Figure 8).

Figure 11.
Colour coding distinguishes between case studies or product analysis scenarios and scenarios with completely new situations

- Splitting the design process into plug-in 'modules' (Figure 9) each being the smallest part of the process. Depending on the needs, a combination of modules can be used. To expose students to the design process in a gradual manner.

Figure 12
Graphical representation of the 'plug-in modules'.

- Splitting the Designing Phase into two, with tools for the second iteration requiring external stimuli (e.g., SCAMPER and Random Word). This is also an ideal place to tap into the process if the recommendation of starting with case studies and product analysis is followed.

4.1.4. Ideas about a toolkit

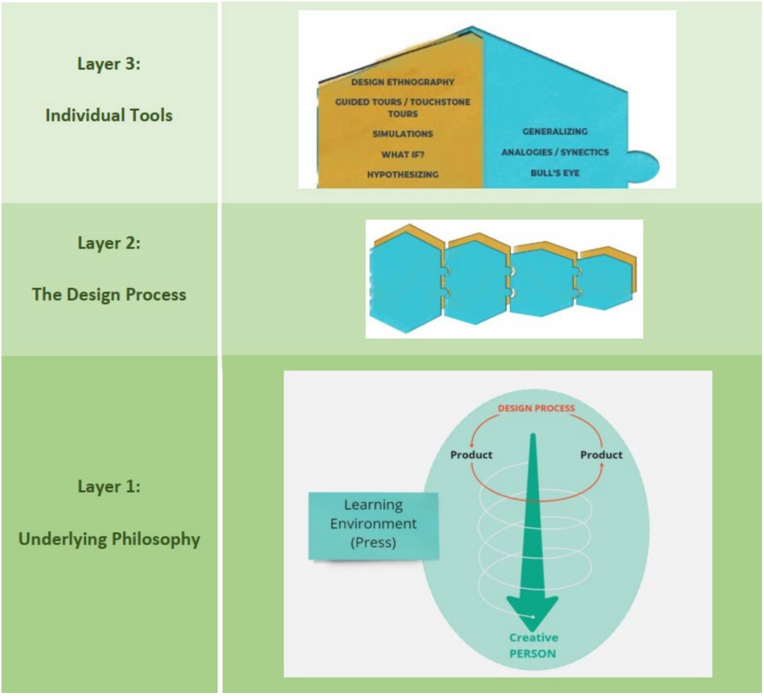
When discussing the idea of a toolkit, all teachers welcomed the idea to vary their current ideas, resources and methods, but showed concern with limiting their autonomy.

To address this concern, the toolkit delivers, and explains, three layers (Figure 10):

(x) A general philosophy addressing the 4Ps of creativity through the spiral curriculum and design process having short and long-term aims.
(xi) The Design process itself, which is made up of iterations of the divergent-convergent creative process.
(xii) The most superficial layer, made up of the individual tools, organised within the design process according to the previous two layers.

For flexibility, teachers are free to decide individual layers or combinations including the combination of all three. Individual tools also include references inviting further exploration.

Figure 13.
The 3 Layers of the toolkit



From this phase, it can be noted that while, collectively, results reflected theories and studies identified in literature, there was lack of homogeneity amongst individual participant with regards to knowledge related to creativity and methods employed to promote it. This re-affirmed the need of the toolkit as intended by this project to ensure students are given the same opportunity to develop their creative potential.

4.2. Phase 2: Toolkit Evaluation

4.2.1. Positive Factors

The main benefits of the toolkit emerging in this phase were the following :

- Helping students in research and exploration, which they seem to find difficult.
- Addressing design fixation through the design process and collaborative tools.

- Helping students to "think deeper about the design process". This highlights a distinction from Phase 1, where it can be argued that reference to thinking about the process is potentially a result of teachers having been exposed to the toolkit.

Other benefits of the toolkit pointed out by the participants were the following:

- The energisers which help set up the right environment so students feel safe and are willing to open up;
- Improved teacher awareness about creativity;
- Alternative teaching methods;
- References included in the description of specific tools;

4.2.2. Negative Factors

The negative factors mentioned were the following:

- Available time to use the toolkit and deliver the syllabus. Based on this finding, items in the toolkit were referenced to the syllabus to convey the message that it is not an addition to the syllabus but a proposed means to deliver it.
- A learning curve until full benefit from the toolkit can be obtained. It can be argued that this is outweighed by the research time that the toolkit saves in the long term.
- A factor related to the layout of the toolkit, which led to modifications in the graphical communication aspect.

4.2.3. Future Opportunities

Recommendations for future adaptations emerging in this phase were the following:

- Adapting the toolkit to be made available for students so they can have more exposure and make independent decisions
- Developing the toolkit on more mainstream media, such as a webpage or a mobile device application.
- Incorporating a feedback platform. This was in fact the idea during the initial design of the toolkit - to be shared and developed in real time in a communal environment. However, was not followed was due to time constraints at the time of development.
- Prioritising the 'Press' aspects of the toolkit as this lays the foundation of all attempts towards creativity and it would make the toolkit transferrable to other school subjects.

5. CONCLUSION

While it is not easy to define creativity, this study has shown that it has multiple facets. The 4P framework – Person, Process, Product, and Press – is used as a basis for exploration. It appears that D&T teachers focus on the Product aspect, giving less importance to the other three. This study has also shown that teachers do not explicitly state the links between D&T and creativity, while not all of them recognise the importance of the design process to foster creativity. In education, creativity is promoted by first removing the barriers and explicitly teaching for creativity. Barriers emerging from this study include difficulty in expression of ideas, and design fixation. Besides the continuous practice of the design process, facilitators of creativity include sensory interaction with ideas, an environment that supports confidence and risk-taking, and teamwork. From the literature review, there seems to be lack of guidance to teachers addressing the multiple requirements of creativity in D&T education. This was also confirmed from the interviews conducted.

To address these findings, the toolkit is based on a philosophy that addresses all 4Ps of creativity, operationalized by the design process. This process is presented as a collection of iterative divergent-convergent creative processes, and the spiral curriculum guides frequent practice of the design process. It also includes provisions for scaffolding to foster creative confidence. A collection of tools is purposefully organised within the design process depending on the relevant phase. The toolkit also includes tools and methods to facilitate idea expression and tools to foster long and short-term creative environment. Evaluation interviews of the toolkit provide evidence that it can promote the high-level thinking required for creativity.

5.1. Limitations and Future potential

Due to time constraints when developing the toolkit, the focus was primarily on the conceptual aspect, with less time invested on refinement of the graphical communication elements. Similarly the toolkit was built on a relatively basic platform. Hence there is potential for it to be developed on a platform that is more interactive and accessible, such as a webpage or a mobile device application. It can also be made more interactive such that it becomes a cooperative space for the community of D&T educators.

5.1.1. Concluding remarks

This study has highlighted the close links between creativity and design in a manner that design can be considered the embodiment of creativity. This, combined with the knowledge creation element of design and the application of that knowledge in real-world scenarios, shows that D&T education is already positioned to prepare students for the present and the future needs of the societies they are already part of.

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Students' Perception about Mechanical Stress and What is Most Important for Learning, during a Practical Task, Using Digital Interactive Lab Description

Caroline Forsell, Bromma gymnasium, Stockholm stad and Royal institution of technology, carfor@kth.se
Per Westerlind, Kunskapsgymnasiet, Göteborg, per.westerlind@kunskapsgymnasiet

ABSTRACT

This study investigated student's knowledge about mechanical stress using material created by the authors of this text. The material was an interactive lab description which can be used as an aid for teachers when teaching solid mechanics. During the studies in upper secondary school in Sweden, students at the technology programme take a general introductory course in mechanics. The participants consisted of four classes from one school in Sweden. They answered a questionnaire before and after the solid mechanics task, 85 out of 107 students answered both questionnaires. A thematic analysis was applied on the material, resulting in 6 groups based on the students' previous knowledge and how much they have learned. To find correlations between the different groups a Oneway Anova analysis with multiple comparison post hoc test was performed. No significant differences were found between groups and how the students rated importance of their preparation, lab description, interactive links, formula book, course book, the teacher or execution of the lab. Significant differences between groups and class, and between the class and the importance of the teacher were found. The teachers' role was most important of all the categories in all classes while the lowest was the course book and the digital links. This study showed that the teacher was important for the students' perception of solid mechanics during this lab and that the interactive lab description played less roll.

Keywords: technology, solid mechanics, practical task, interactive links, learning

1. INTRODUCTION

The technology course is mandatory in Sweden and is studied in all nine years of compulsory school. It has a broad curriculum where students are introduced to both the engineering aspect as well as to the importance of technology in daily life. The course also highlights, among other things, different technological advances done in the past as well as the importance of stable constructions (Skolverket, 2019a). At the end of the compulsory school, students apply for an upper secondary school programme and about 8.4% choose technology (Skolverket, 2023b). In the program all students study a compulsory introductory course that includes ethical perspectives on technology, and the technical properties of materials among other things.

Solid mechanics has played an important role in the technology course plan and even though its role may have lessened it is still widely used when teaching material calculations. Materials is a big aspect and still play a big part of the technology course criteria's (Skolverket, 2022). Teaching is an activity of great complexity and the role of the teacher for student learning is well established (eg. Darling-Hammond, 1996). This role may concern, for example, relational aspects where a good teacher-student relationship support student learning (Hirsch, 2021). Furthermore, the teacher's attitude towards the subject is also of importance, previous studies have shown that teachers usually do not teach subjects they have no or less confidence in (Holroyd and Harlen, 1996)

A didactical model may be used to explain and reason about the different teaching approaches that a teacher may conduct. The teaching approach depends on the context that is to be taught (Wickman, Hamza & Lundegård, 2018). This is also discussed by Hattie (2003). The didactical model should not only be used when planning and conducting a lesson but also in its evaluation (Jank & Meyer, 2003).

Many studies have investigated how digital aids can help students performing practical tasks (Barrow & Rouse, 2009; Karlsudd, 2014; Usulu & Usulu, 2021). An international study reported that the better adapted a digital aid is for the students, the less stress they feel during practical tasks. (Inquimbert, 2019). Thus, an interactive digital material was constructed specifically for a lab experiment involving strain and stress. Additionally, earlier research conducted by the main author (2019a) showed that the attitude the teachers have when approaching solid mechanics during lessons was important for the students learning. In the study some challenges regarding teaching solid mechanics were identified. The present study focused on one of these challenges, namely the learning of new terms and concepts like stress and strain. It was designed to evaluate the impact of digital support on students learning also considering the role of the teacher.

2. AIM

The aim of this study was to evaluate a material designed to support student learning. More specifically:

- What do students know about mechanical stress before and after doing the experiment?

- What do the students perceive as helpful in the material in their learning about mechanical stress?

3. METHOD

3.1. Participants

The participants consisted of 107 students, in four different classes all studying at one school in Sweden, and all classes had different teachers. None of the participants had any previous knowledge of solid mechanics. All the students got two forms with identical questions to answer, one before the experiment and one after, 85 students answered both forms. Before the lesson the students were informed that the participation in the study was voluntary and that the answer to the questionnaires were anonymous. The ethical advice and rules for the Swedish research council where followed (Vetenskapsrådet, 2017).

3.2. Experiment

An interactive lab description of a tensile test was designed and implemented. The questions to the students shortly described the term so that the students would remember from earlier studies in grade school. The questions were as follows:

(i) Mechanical stress occurs in a material when you try to pull out the material so that it becomes longer. Mechanical stress is force pushing on a surface that is perpendicular to the force. What do you know about mechanical stress?

(ii) Strain occurs when pulling a material. Strain is how much you extend a material relative its original length. There is a relation between strain and elongation. What do you know about this relation?

(iii) Stress and strain relate to each other. When you draw a graph (curve, as a mathematical function with appearance f(x)= x) that describes the relationship between mechanical stress and elongation, you get a certain appearance that is unique for the material being studied. What do you know about the graph? What does it describe?

The students were also asked to rate the importance of different learning aspects on a scale where six was the most important and one was the least. The options they had were; their own preparation, the lab description, the interactive links, formula booklet, course book, the teacher, and the execution of the lab.

3.3. Thematic analysis

A thematic l analysis (Braun and Clarke, 2006) was used to find groups among the students depending on how they experienced mechanical stress. Significant statements phrases and sentences where extracted. Different themes where generated where statements with similar meaning were put together to form themes. Themes where then summarized and described. Six groups of students (Perception group1-6) with different themes were identified during the analyses. The different groups had different perceptions of mechanical stress before and/or after the performed task.

3.4. Statistical analysis

A Oneway Anova with multiple comparison post hoc test (Ostertagova et al., 2013) was used to find associations and relations between the different groups generated in the thematic analysis. The mean and standard deviation for the students' ratings were also calculated. The statistically significant relations between classes, the perception groups with the same theme, and what the student rated of importance was investigated.

4. RESULT

In table 1 the results from the thematic analysis are described; student answers are used for exemplifying the perception group descriptions. In three of the four classes most students were found in perception group one. Most of the students (perception group 1) learned less than we hoped and even though the provided material was some help it was not the most important thing compared to many other factors.

Table 1.
Groups of students with different perception on mechanical stress.

Perception group	Example of an answer before the task	Example of an answer after the performed task
<u>Group 1</u> **Before the task: Students know nothing, or very little, about mechanical stress, strain, or about the relationship between the two. They expressed this by writing things that were wrong or by not writing anything at all.** **After the task: Students express some understanding of the concept mechanical stress but no or very little understanding of what how affects material or the relationship to strain. They could also have expressed some understanding of the relationship but nothing about the concept of strain.**	"No idea, no clue, do not know"	"It's the power divided by the area in mm^2." "nothing, doesn't understand what I should have realized with the graph"
<u>Group 2</u> **Before: Same as group 1** **After: Express some understanding of mechanical stress, strain and the relationship between them.**	"Nothing, nothing special"	"It depends on epsilon and the stress." "It is the mechanical stress. Elasticity".

<u>Group 3</u> **Before: Express some understanding of the concept mechanical stress.** **After: Express some understanding of strain and the relationship between strain and mechanical stress. The student also expresses an understanding of the concept mechanical stress.**	"Looked a little at it. I know F/A = some stress. Beyond that I do not know more." "I know there is a relation between them. I do not know how you use it or what equation I should use." "I know that the graph probably gets a bigger y value the more stress you have and enough stress result in that the material will break." "It depends a lot on different material."	"I know now that F/A = stress. Thus, when you pull a material the stress will increase depending on how big area you have." "I know now that strain is depending on the elongation and the original length of the material you had." "I know that the graph descries the correlation between stress and strain."
<u>Group 4</u> **Before: Express an understanding of the concepts mechanical stress and strain and the relation between them.** **After: They do not express any difference in understanding before the task as compared to after the task.**	"A force on object that you pull." "A Rubber band." "But I do not know more about this." "Do not know anything but my guess is that there is a relation between the length of the material and the force you pull with. There is also a relationship with what material it is. Rubber can stretch more than stone." "Have absolutely no idea."	"An object is stretched when a certain stress occurs on the object. The more stress, the more strain." "It describes the relationship between the strain and stress."
<u>Group 5</u> **Before: Express no understanding of the concepts stress and strain or the relation between them** **After: Express no understanding on the concepts stress and strain or the relationship between them.**	"Nothing". "The stress increases when you stretch something. " "High stress means that the object you are pulling stretches a lot." "Proportional increase in the graph."	"Mechanical stress in a material occurs when you try to pull out the material so that it becomes longer." "Stress is a force that is applied on a surface that is perpendicular to the force." "Proportional relation. It should be equally constant."
<u>Group 6</u> **Before: Express some understanding of the concept mechanical stress** **After: No difference in understanding after the task than before.**	"Mechanical stress in a material occurs when you pull a material, so it gets longer."	"You calculate stress by F/A = the force divided by the area."

Table 3 presents the results from the One-way Anova analysis. There was not much difference in importance between for example teacher and digital links. However, there were significant differences between groups of students with different perceptions and different classes they belonged to ($p<0.01$) and, for the group versus teacher and the digital links, see table 4. For two groups, one and six, the teacher seemed to be of greater importance than for example the digital links ($p<0.05$). There was no significant difference between groups in the rating of the links but in the rating of the teacher ($p<0.05$).

Table 2.
Number of students in the four classes divided in the different perception groups.

		Groups						Total
		1	2	3	4	5	6	
Classes	1	11	4	5	0	6	2	28
	2	11	2	2	0	2	1	18
	3	16	1	0	0	3	5	25
	4	2	0	3	2	3	4	14
Total		40	7	10	2	14	12	85

Table 3.
The importance of different aids during the lab for the different perception groups, rating 1-6 where 6 was most important.

Groups	**Own preparation**	**Description of lab**	**Interactive links**	**Formula book**	**Course book**	**The teacher**	**Execution of the lab**
Total	2.76	2.51	2.96	2.78	3.25	2.79	3.24
Mean Std	0.56	0.76	0.47	0.45	1.16	0.74	1.16

Table 4.
The importance of a) The digital links for the different groups b) The teacher for the different groups. Rated 1-6 where 6 was the most important.

Groups versus digital links	**Mean**	**Std.**
1	2.60	1.73
2	2.26	1.97
3	2.91	1.92
4	3.71	2.56
5	3.33	2.58
6	2.92	2.07
Groups versus teacher	**Mean**	**Std.**
1	4.25	2.12
2	2.00	1.83
3	2.83	1.70
4	2.25	2.32
5	2.39	1.98
6	3.00	1.99

5. DISCUSSION AND CONCLUSION

The present study found a correlation between the importance of the teacher and which class the student belonged to when learning something new. However, there was no significant correlations between the student perception groups and the importance of the digital links nor the class they belonged to and the digital links.

The result implies that the teacher was very important for the outcome of the task and depending on which specific teacher the student had the teacher was more or less important.

This might have been due to that teaching is a very complicated task (Darling-Hammond, 1996) and that the relationship between the teacher and student is important for learning (Hirsh, 2021). Thus, we think the importance of the teachers dominated in our study and thus other significant differences might not have been not seen. Maybe with less help from the teachers we could have investigated how much help the digital aids gave to understand the concepts stress and strain. It might also be that the teachers facilitated the use of the digital aids and the students rated this as teachers' importance (Collison and Cook, 2013). The importance of using the digital links and exactly how it is used thus needs to be further investigated.

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Embedding Computational Thinking into Authentic Technology Practice

Wendy Fox-Turnbull, University of Waikato, wendy.fox@waikato.ac.nz
Shaoqun Wu, University of Waikato, shaoqun.wu@waikato.ac.nz
Tiana Mayo, University of Waikato
Matthew Stafford, University of Waikato
Swati Gulati, University of Waikato

ABSTRACT

There is recognition internationally about the need for digital technologies within the curriculum. Computational thinking is a critical component of this and is defined as an approach to problem-solving, designing computer systems, and understanding related human behaviours, while drawing on fundamental ideas of computing. Therefore, it is critical that all students acquire computational thinking skills. Technology practice is most successful when embedded within authentic contexts, thus this paper presents a study that facilitated the learning of two concepts of computational thinking: sequencing and orientation within culturally embedded technology practice. The study's vision is to teach mainstream Māori learners from low socio-economic backgrounds concepts of computational thinking within authentic cultural contexts. The research design drew on Māori values and practice that situates learning within authentic Māori contexts. Kaupapa Māori pedagogies were used in our design-based intervention programme to achieve the research goal. The focus of the project was to improve digital technologies learning outcomes to ensure Māori tamariki (children) see themselves as comfortably situated in a digital world.

Keywords: digital technologies, computational thinking, authentic technological practice indigenous knowledge.

1. INTRODUCTION

Digital technologies have facilitated developing a context-rich teaching and learning environment that increases learners' participation in quality authentically situated technology education (Turnbull, 2002). The progress of society in various fields (economic, educational, industrial, and social) today is strongly coupled to the integration of digital technologies (Caballero-Gonzalez et al., 2019), among which computer thinking is being recognized as important and foundation skills. Research suggests that teachers need to be better equipped to teach digital technologies to ensure their students' capabilities and dispositions are such that they are well placed for a future in high-tech industries and rapidly changing work conditions (Falloon, 2015). This has led to an increasing interest in developing computational thinking at the primary school level before students are 10 years old (Bell et al., 2014). The study reports the development of computational thinking skills for young New Zealand's indigenous Māori (New Zealand's Indigenous people) students situated within authentic cultural practice and context.

2. LITERATURE REVIEW

2.1 Digital Technology and Computational Thinking

Computational thinking assists learners in understanding of problems and determining the correct tools and methods for solving problems (Mohaghegh & McCauley, 2016; Zeng et al., 2023). Brennan and Resnick (2012) identify three dimensions of computational thinking: 1) computational concepts such as sequencing, iteration, loops, and parallelism, 2) computational practices such as testing and debugging, reusing or remixing others' work, and abstracting and modularising, 3) computational perspectives, that is learners seeing themselves as more than consumers but rather participants who express and question themselves and connect with others. Zeng et al. (2023) found the above framework appropriate for children.

Studies in the last few years suggest many teachers undergo considerable professional development to understand and effectively teach computational thinking and highlight the needs to prepare teachers in junior classrooms irrespective of the resources provided to them (Bell et al., 2014; Bell & Duncan, 2015; Duncan et al., 2017; Geldreich et al., 2018; Yadav et al., 2016). Bell and Roberts (2016) report teachers with little or no experience teaching computational thinking-related topics have identified unexpected opportunities for integrating computational thinking with other subjects such as maths or into the activities that enhance the development of collaborative skills among students. Therefore, reluctant teachers may be convinced to add computational thinking to an already crowded curriculum if they can see multiple connections and benefits for their students.

2.2 Working with Māori learners and technology

Learners need to see their cultural practices in the learning (Tiakiwai & Tiakiwai, 2010). Teachers' beliefs about culturally responsive teaching, attitudes toward computational thinking, and STEM practices were flexible and differed in different contexts. According to Leonard et al. (2018) using culture as a hook to engage underserved students to learn essential computational thinking skills is virtually unresearched.

Axell (2020) Kaupapa Māori (perceiving the world from a Māori perspective and normalising Māori values, behaviours, and understandings) is underpinned by the implementation of Māori processes and understandings within a Māori philosophical framework (Hargraves, 2020; Hoskins & Jones, 2017. In terms of computational thinking in Kaupapa Māori, Mohaghegh and McCauley (2016) state that there is little research on the development of Māori students. There are, however, documented links between cultural identity and technological artefacts. In in her study of indigenous technologies of the Sami people in North Sweden Axell (2020) found that technology assisted the development of children's cultural identify, especially when they understood the role their cultural artefacts play within their culture and society. This was assisted by comparing the old with the new, for example a lávvu (mobile home similar to Native American tipi) with a caravan, shoe hay with socks and sinew threads with dental floss. The message was that although some knowledge is old, it remains important and relevant today and that new and old technologies are often used side by side. Rice et al. (2016) also identifed the links between using technologies (social media) with strong cultural identity and community and family connections in indigenous Australian communities.

There is a need to promote technology and computer science to Māori students and for Māori to be trained as developers and creators of technology and digital solutions, rather than just users and consumers of existing technologies. The above studies suggest that one way to do this is to current past indigenous technologies with future ideas, artefacts and processes. It is of critical importance to include computational thinking in the curriculum that is particularly accessible to groups of people who are technology consumers but are not traditionally pictured as employed in the fields of computer science and technology, such as Māori, minority ethnic groups, and women.

3. METHODOLOGY AND METHODS

Qualitative methodology underpinned by theoretical concepts of Kaupapa Māori (Hoskins & Jones, 2017) and Constructionism (Papert & Harel, 1991) guided this study. Within a constructionist paradigm, meaning is constructed by people as they engage with the world they interpret, which facilitates sense-making of the same reality in different ways (Crotty, 1998). Kaupapa Māori enabled the rethink of academic conventions by including cultural expression, values, and ethics, and aims to achieve higher academic standards for Māori (Hoskins & Jones, 2017). It promotes Māori-centered approaches in terms of questions, methods, motivations (Stewart, 2021). This research was implemented using a Māori perspective with an aim of increasing learning outcomes for Māori (Hoskins & Jones, 2017; Stewart, 2021). The research question was "How can teaching computational thinking and understanding of technology be enhanced by planning and implementing culturally authentic activities with young Māori learners?

In total twelve students and two teachers participated in the study (Table 1). Ethical consent was obtained through the participating university. Purposeful sampling was used to identify a school with a high Māori roll in a low socioeconomic area. Access to the school was through the principal, with two teachers of students in Years 1-3 (5-7 years old) agreeing to participate in the study. All children in the class of 35 participated in the planned learning. Information letters and consent forms were sent to the parents. Data was gathered only from children who, along with their parents, consented to participate (n=12). Participants were guaranteed confidentiality; however, anonymity was not guaranteed as data included photos and videos of students in their school uniforms. The results reported in this paper drew on focus group interviews with students, observations, and videos of students at work, teacher planning, and student work samples.

Table 1
Study Participants

Teacher Pseudonym	**Ethnicity**	**Sex**	**Years teaching**	**Years at this school**
Whaea* M (WM)	Māori	F	7	5
Whaea O (WO)	Pakeha**	F	10 months at start of study	1
Student Pseudonym		Sex	Age	School year
Peta	Māori	M	6	2
Colin	Māori/Pakeha	M	7	3
Ahere	Māori	F	7	3
Ihaka	Māori	M	7	3
Bobby	Pacifica	M	5	1
Gerald	Pakeha	M	6	2
Sua	Pacifica	M	5	1
Danny	Māori	F	6	2
Ana	Māori	F	5	1
Kali	Māori	F	6	3
Ihu	Māori	M	6	6
Hanna	Pakeha	F	5	1

** Term used for respected females- literally means mother, aunty. Often used in schools with high proportion of Māori students*
*** Term used in New Zealand for non-Māori, usually of European descent*

Students engaged in constructing their learning through a set of scaffolded activities to teach them the concepts of sequencing and orientation in relation to programming a simple robot -Bee-Bots (Figure 1), with the long-term aim for the students designing an App to assist newcomers to navigate their way around their school. The lead researcher and the teachers co-constructed a unit of work (Appendix 1) which the teachers implemented. The research team assisted implementation when needed. Each teaching session was video recorded. Focus group interviews (Appendix 2) with the students occurred before and after the unit.

Figure 1: Bee-bot® in action in the classroom

Data was analysed using thematic analysis aiming to understand the students' learning in computational thinking within authentic technology-related contexts. The researchers coded and recoded the data to identify key themes with the aim to understand meaningful reality as suggested by Crotty (1998).

4. FINDINGS

Students in the study learned computational thinking concepts from a te Ao Māori (Māori world view) perspective. Two key themes were identified: culturally informed pedagogy and student engagement that demonstrated a developing understanding of the computational thinking concepts.

4.1 4.1 Culturally Informed Pedagogy

Culturally informed pedagogy is reflected in four aspects: learning context, use of te reo Māori (Māori language), relationship building and ownership of learning. First, as illustrated below, the teachers set up a context relevant to the students' lived experience and their whānau using story-telling, daily routines and role-plays.

> WM: WO and I were talking tonight, there's the disco and we have lots of new tamariki[children] who have come to our school and some of their whānau probably don't know where the hall is, they probably don't know where to park their car…they might get lost. We have lots of gates.

Examples are that students were taught the importance of sequencing through engagement with a Māori legend, 'How Maui slowed the Sun', WO reminds students the story of Māui taming Tama-nui-te-Rā sun) and shows them the cards and how they need to be organised into the correct order of events' (observation notes 2 November). One activity required the students with their dog to navigate to the marae meeting a friend and gathering kumara (sweet potato) on the way by placing forward, back, left and right arrows on the template provided (Figure 2).

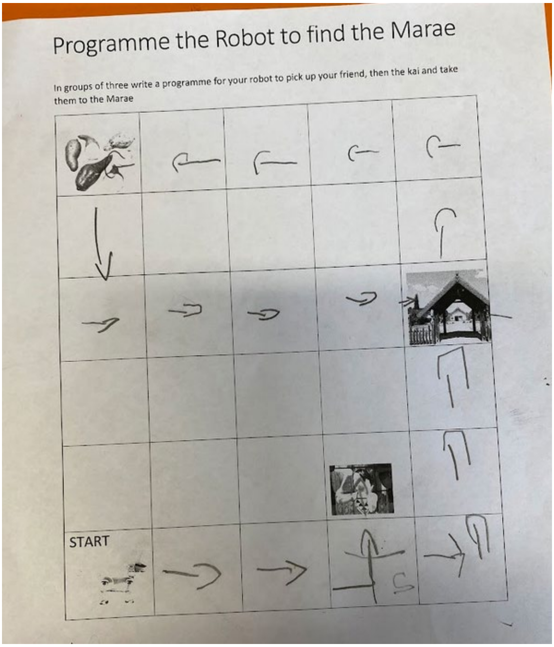

Figure 2: Peta, Kaihautu and Bobby's programme to take the dog to the marae, collecting a friend and kai (food) in the way

Other examples include role-plays that are related to the students' everyday lives to illustrate sequencing such as going to toilets shown below.

> WO: You imagine if you were a computer or a robot right. So I am a robot and WM is going to tell me what to do and I am going to do it.
>
> WM: Sit down, stand up, turn around, take two steps maui [left], and three steps matou [right].

> *WO follows the instructions in order*
>
> Student: You have to tell the directions
>
> WO: Yeah, so from the start, what happens first and then next. So sequencing for going to the wharepaku [toilet], what do you do first?
>
> Student: Open the door
>
> WO: Then we…
>
> Student: Lock the door
>
> WO: Then we…
>
> Student: Pull our pants down…….

Second, use of te reo Māori was frequent and natural, constantly inserted as a part of everyday classroom dialogue as demonstrated by Whaea O (Miss O), with English words added by the writer as she gives instructions for one of the activities.

> WO Yeah otherwise it gets pakaru [broken] and then just doesn't work properly.
>
> WO: Your job is to figure out, some of you are going straight to the marae [communal meeting house]. Some of you need to start here, we all start at the same place. Then we need to go pick up our friends. Then we need to go and get the kai [food] and then we need to go to the marae. You need to figure out how many steps forward you need to take to get to your friend, then you are going to have to turn left or right to get to the kai.

Third, strong relationships were developed and established between older and younger students and between students and teachers. Tuakana/Tēina teaching (tuakana -older & more capable) and tēina (younger peers) is key to Te Ae Māori [Māori word view]. The extract from researcher observation notes demonstrates this.

> Students are directed to read the packs and use the pictures as clues to put the story in the right order. Tuakana have been put in charge as leaders of each group.

The teacher in the classroom developed very strong relationships with their students. The classroom climate was one where failure was accepted and respected and then turned into opportunities for learning as evidenced by researcher observation notes, "Groups who were unsuccessful were shown which part of their sequence was incorrect and were sent away happily to reconfigure and test again" (observation notes 24 November).

The fourth pedagogical strategy related to students' ownership and co-construction of their own learning. Initially using the template illustrated in Figure 2.

> WO: Who knows what this might be? Ahere?
>
> Ahere It might be a map.
>
> WO: That's right, it is a map. What can you see on the map?
>
> Multiple students: A marae, kumara, kete [basket]
>
> WO: Your job is to figure out [where you want to do and what you want to do], some of you are going straight to the marae. Some of you need to start here. ……. You need to figure out how many steps forward you need to take to get to your friend, then you are going to have to turn left or right to get to the kai. You might want to draw how you are going to get there.

After completing this task, the students were given the option of writing code for a Bee-bot to navigate their pathway, selecting their own starting point (Figure 3). To scaffold learning for those who found coding Bee-bot difficult, some students began by writing and practicing their coding using a 'teddy bear' manipulative (Figure 4).

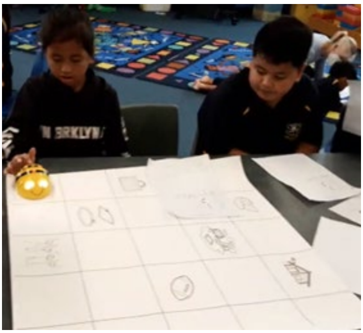

Figure 3: Programme their own journey to the Marae to the Marae with Teddy manipulative

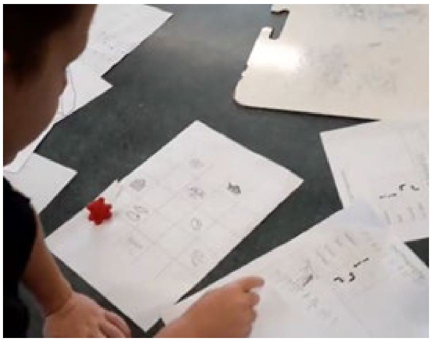

Figure 4: Programme their own journey

Next the students walked around the school and drew pictures of significant school landmarks and then placed them on their own blank map. "Students create their own maps that mirror the locations of the class's big map. The locations have been chosen and designed by the students based on real locations in the school" (Observation notes 21 November 2022). Students then wrote code to 'navigate' around the school.

WO: You can start anywhere, I might want to start over here, ……. Or maybe my main entrance, the office, my office might be over here. [points to different spaces on the map while talking].

4.2 4.2 Student Engagement and Emerging Understanding of Computational Thinking and Coding

Sequencing and orientation to the two concepts of computational thinking specifically taught in the unit. The extract below showed that most children could identify left and right. “Almost all of the students raised their left hand, a few realised their mistake and changed” (observation notes 3 November). Some tēina needed prompts, for example letters on their hands as Bobby mentions below.

WM: It’s like they were a computer, and you were inputting directions

WO: Yeah, you guys were computers, and I was giving you information and you were following my instructions.

Bobby: The reason I was there was because of the letters

WM: Oh, the letters, but what about when we took the letters away, you still knew

Students clearly understood what the term sequencing meant.

WO: Who knows what sequencing means? What does sequencing mean? If I say you going to put this in, you are going to sequence these pictures in…?

Student: Order!

Student: I remember what order is, you put them in the right order.

Students appeared to gain an understanding of map layout in relation to their school, incorporating orientation and sequencing relevant coding in context.

WO: So, what do you think we need to make it look like a map?

Student: We need pictures on it. ……..

WO: What kind of map is going to be of?

Student: The school

WO: Oh, so what does it need on there? It needs…

Student: The office……

WO: Someone is going to choose because the office is the front of the school, isn't it? So, if I was a manuhiri, a visitor, I would start at the office, because I have to sign in. [Kali is then invited to stick a picture representing the office on the 5x5 grid map. She places the picture of the office on the lowest left-side corner of the grid]

WO: OK, so do you think that's a good place to put the office?

Multiple students: No

WO: Why not? What's next to the office?

Bobby: The car park

WO: Where's the car park going to go? Over here [indicates off the map]

Multiple students: No

WO: [Indicates to the student to return to the grid map] Haere mai! (hello), so where would be a good place if we know…the office is in the…?

Student: Middle

WO: The office is in the middle. [Kali picks up the picture of the office and places it in the centre column and the lowest row of the grid]

Some of the students developed an understanding of the concept of a map and its use for navigation. This set them up for the necessity of sequencing the places to be visited in relation to the map (Figure 5) and therefore giving a foundation for the sequencing of a programme for navigation.

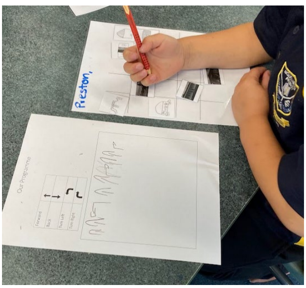

Figure 5: Programme their own journey to the Marae around their school, having situated specific places.

Data suggests that by the end of the unit, that all students understood the concept of programming a robot (Bee-Bot) by giving it multiple sequenced instructions. The tuakana (older students) undertook self-correct debugging in relation to mapping a route. "After showing the kaiako his programme on paper, Ihaka entered his programme into the BeeBot and completed the task on his first attempt" [observation notes 24 November 2022].

> Gerald is testing his programme on the map by using a manipulative and checking that each step in his programme works. After showing the kaiako, Gerald enters his programme into the BeeBot and signals it to start. ….. Gerald was able to complete the task on his first attempt. Ahere fails on her first attempt and then succeeds on her second attempt. Ihu succeeds on his second attempt. Peta was able to complete the task on his first attempt and Sua was able to complete the task on his first attempt. Two groups utilized the backward movement feature as part of their sequence [observation notes 24 November].

Some tēina (younger students) confused 'forward' with 'up', "One student, while entering his sequence into the Bee-Bot, had it facing right but input his sequence as if the bot was facing up". Others had difficulty transferring a three-dimensional journey on a map to the linear positioning of code on a page. For example, "Ihaka attempted to test his sequence, however, once the directions were off the map and in a sequenced line, he could not replicate his sequence on the map" [observation notes 15 November]. To assist with this the teachers introduced a manipulative (plastic teddy) which the students used to test their code one step at a time before entering the whole sequence into Bee-Bots.

> Without manipulatives, the students struggled to visualise the sequence working. It may be that the students perceived the left and right turn directions as turning a corner as opposed to a 90 ° rotation.

Another issue the students experienced was the assumption that the 'turn' command in Bee-Bot included a step forward. This was either corrected by the teachers and researchers working with the students or self-discovered. "[Researcher 3] clarifies this with Colin and explains that the turn does not include movement and that we stay still when we turn" [Observation Notes 14 November].

5. DISCUSSION

As the tauira (students) in this study were predominantly Māori, a te Ao Māori perspective involved them interacting with content that was based on Māori values and beliefs, using Māori learning practices and engaging with te reo Māori. The concepts of computation thinking were embedded in the students' cultural context in two ways: through the learning context and through the pedagogical strategies. With regards to context, kaiako (teachers) use a te Ao Māori focus as part of their Kaupapa (plan) to establish an authentic learning context for their tauira (students) where their cultural identity and everyday lives are reflected in their classroom activities. The context of tasks undertaken, and the purpose of the tasks were contextualised through the tauira's connection to their land and to their whanau. For example, a Māori legend was used in the introduction to the importance of sequencing, the sequencing objectives are the physical locations of their school and town, and the elements of home and whanau life are integrated into the lessons in storytelling. The final test programme requires students to direct Beebot to pick up 'Nan', get a kete [basket] and gather kūmara (sweet potato) before arriving at the marae. Such an approach aligned with the findings of Leonard et al. (2018) that the students were engaged in a space they were already familiar with and they can see themselves as developers and consumers of technology as well, which is the need for teaching computational thinking that Litts et al. (2021) emphasise.

With regards to teaching strategies, te Ao Māori is used through wānanga (programme of work) and ako (learning), and tauira who were struggling with understanding their own identity as Māori and with the learning concepts were given a safe space to express themselves free from judgement. Firstly, the integration of te reo Māori was seamless throughout the unit. As the words were intermittently changed between English and te reo Māori, kaiako (teachers) would not stop to offer a translation. This encourages the tauira to focus on the lesson and shows that their language is valued in the classroom. Secondly, the kaiako do not assume there is only one way to learn and assume all tauira can learn with existing knowledge and skills. Their multifaceted approach to learning gave tauira the confidence to explore digital technology according to their own strengths. To be specific, the kaiako were very vocal and explicit about learning, showing the tauira that they did not have all the answers and that they were sharing the same risks as the tauira in the learning experience. Thirdly, the kaiako used Tuakana/Tēina, allowing students to work together and assist each other as strong relationships between whanau and school are critical to engaging Māori learners. Berryman and Forde (2017) promote school home relationships which require teachers to be aware of the students' cultural backgrounds and their own cultural biases. Ensuring they feel comfortable and welcome at school is an important part of this.

Finally, Bee-Bots were used throughout the unit and as a final assessment tool and the students were thoroughly engaging. Is using Bee-Bots necessary in learning computational thinking? A person could walk on a map on the floor following the written sequenced instructions from a peer. However, the movement of the Bee-Bot in the three-dimensional setting to a linear two-dimensional set of arrows, a form of abstraction, tests students' abstraction skill, one of the challenging aspects of computation thinking. Therefore, we argue that a significant advantage of Bee-Bots was that they were programmed, trailing and debugged as a whole or partial programme rather than step-by-step as was evident with the testing with people role-playing robots.

6. CONCLUSION

This study investigated the teaching and learning of two specific computation thinking aspects (navigation and orientation) within Brennan and Resnick's (2012) three-dimensional framework—computational concepts, computational practices and computational perspectives. Students were introduced to and engaged with two specific concepts—sequencing and orientation—through programming Bee-Bots and undertook authentic technology practice to determine the reason for their learning. We particularly focused on computational perspectives which were a critical component that encouraged students to understand programming as an important aspect in te Ao Māori them and themselves as Māori. This study suggests that role-play and manipulatives are appropriate scaffolds to basic programming but not an end point.

Several limitations of the study were identified. Learning with manipulatives was introduced quite late in the study. This scaffold would have been useful earlier on to assist the transition from 3D thinking to 2D lines of code. This may have reduced some student confusion. In addition, opportunities to teach debugging were not capitalised on. However, debugging became a critical aspect when testing code and therefore should have been taught in parallel with the other two concepts. Unfortunately, the unit was not completed, and students did not reach the point where they could apply their learning to code the actual app. This was partly due to COVID 19 absences and an underestimation of how long the learning took. Despite this, data suggests that tauira were engaged, developing understanding about the role of sequencing and orientation in relation to coding a simple robot. The next step in the research project will include specific foci on testing and debugging and further development of the ideas of abstraction which presented the biggest challenge to the students.

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Subject Knowledge in D&T Teacher Education: Exploring the Gaps

Karen Fuller, Manchester Metropolitan University, karen.fuller@mmu.ac.uk
Torben Steeg, Manchester Metropolitan University, torben@steeg.co.uk

ABSTRACT

Determining the key subject knowledge that should underpin D&T Teacher education in England has never been easy. The fundamental range of the subject (with a scope of materials that includes food, textiles, engineered materials, computational systems… used to design and make products across a limitless extent of context), continuing developments in many of the technologies that underpin it, the breadth of experience that entrants to D&T teaching bring with them, the heterogeneity of approaches to D&T subject matter in schools (including the move in many English schools to teaching some of the above areas, especially textiles, through Art & Design) and ever changing statutory and examination requirements all have their influence. In the past the D&T Association (2003) has provided guidance, but, as noted by Martin as long ago as 2008, this guidance has lost relevance as the landscape has changed. There are, of course, in addition to all the above, broader debates that are current about the role of subject knowledge in school education, and these have led to various explorations about how the fundamentals of subject knowledge in D&T should be constructed. In this paper we describe the way that subject knowledge content in our PGCE D&T curriculum has been, and still is, evolving in response to these diverse and not always complementary forces. Underpinning this, using survey data from past and present ITE students and placement schools, we explore how the subject knowledge content of our PGCE course matches with the needs of our students and the curricula of their placement and first teaching schools. We end by suggesting possible avenues of development for D&T ITE subject knowledge in the English context, and draw out some principles for building a relevant and robust subject knowledge base for teacher education in D&T.

Keywords: ITE, Subject Knowledge, Curriculum Development

1. INTRODUCTION

Preparing people to be teachers is complex. Preparing them to teach D&T is at least as complex as any other subject; the breadth of subject knowledge encompassed by the subject is broad, the knowledge people bring to a training course is generally comparatively narrow but, we hope, has depth. One task of teacher preparation is to, add some breadth to this depth. Notably similar issues arise in the education of professional designers (Peters, 2012).

The topic of D&T subject knowledge has been made more challenging for schools by curriculum changes that have focused on the raising the profile of subject knowledge in school subjects leading to a relatively new national curriculum for D&T in English schools (DfE, 2014) accompanied by new GCSE specifications (this is the national exam for 16-year-olds) (Ofqual 2021a, 2021b). Alongside these changes have been national debates about the nature of knowledge in school subjects (Baynham & Frank (2021).

2. SUMMARY OF THE RESEARCH

Every year we adjust the detail of the subject knowledge elements of our PGCE. These changes take into account the statutory framework, the big ideas of D&T (Barlex et al, 2017) and the feedback of students and mentors. Every year we find ourselves constrained by the limited time that students have in the university in a 1-year PGCE course. Always in questions is the way that we balance subject knowledge development between learning in our university environment and learning in placement schools. So, a question that arises is, are we providing a reasonable foundation of subject knowledge that gives our partner schools a platform to build on.

To explore this question, we surveyed our students asking how well prepared they felt for their placements in terms of their levels of subject knowledge. At the same time, we asked the school mentors how well prepared they felt the students were. A survey approach was chosen to allow busy mentors and students, during a school placement, to provide a comprehensive overview of subject knowledge demands without demanding too much of their time. Clearly there are limits to the evidence one can elicit this way, but we were pleased by the high response rates (reported below) and the overview these provided. The surveys used questionnaires in Microsoft Forms with a mix of open and 'pick from a list' questions.

1. RESPONSES TO THE SURVEYS

Data was collected from our current students during their first school placement, and we had a 100% response (n=11). At the same time, we asked their mentors a partially overlapping set of questions and got responses from 15 mentors; this included some responses from the same school and in what follows we have counted these only once (this represented 12 schools; one student left the course partway through the placement). We repeated the mentor survey near the start of the students' second placement and had responses from 4 new schools; their data is also included below, where pertinent. The total number of individual schools represented was thus 16.

At the same time, data was collected from students from previous years and their subject mentors covering the years 2018-19 to 2021-22. We had responses from 33 previous students out of a possible 50, and 9 subject mentors.

1.1. Aspects of D&T taught at KS3 in your school.

1.1.1. Current students and mentors

The first question asked students about the topics within D&T that they were teaching, at Key Stage 3 (KS3 11–14-year-olds), on the placement, similarly we asked the mentors about the range of D&T topics offered at KS3 to the school's pupils (Table 1).

Choosing the 'topic' headings for this question raised many questions for us; we wanted to capture the broad kinds of knowledge content that students and schools would recognise from units of work descriptors, while avoiding getting into a highly detailed list of content. We recognise that there are many other ways that we could have carved this up (for example asking about units of work that are 'mainly making', 'mainly designing' etc., or asking about the details or openness of the design contexts driving the work). However, we were particularly keen to focus on subject knowledge, and scrutiny of the students' placement timetables suggested the topic headings shown in Table 1 would be recognisable to both target audiences.

Table 1:
KS3 content (current students and mentors)

	Content taught by PGCE students (n=11)	**Content offered by the school (n=16)**
CAD	3	12
Electronics	2	11
Engineering	0	9
Food & Nutrition	8	14
Graphics	2	10
Hospitality and catering	1	4
Mechanisms	2	5
Metals	1	8
Plastics	1	11
Product Design	2	12
Structures	1	7
Textiles within art	3	4
Textiles within D&T	7	15
Timbers	2	13
Other	0	2

In response to a request to detail any 'Other' topic areas, the list we got was largely comprised of items that we viewed as either subsets of the topic headings above or core aspects of D&T; for example, 'machines, tools', 'gears, mechanisms, forces', 'CAD/CAM', 'biomimicry', sustainability, and 'aerodynamics'. There were also references to aspects of the curriculum that D&T departments have responsibility for, but that we don't tend to consider to be core to a D&T PGCE; in particular aspects of Art and Design ('Art, craft and design:3D', 'Photography', 'pottery') but also 'Child Development'. These responses are indicative of the rather porous disciplinary boundaries that 'D&T' in schools often experiences, driven by combinations of staff shortages, limited funding and timetable pressures. It is noteworthy that we felt we should include 'Textiles within art' in our list of content as we see this increasingly being seen as a responsibility of the D&T department.

However, some 'Others' represent items that we might well include in any future iterations. These include robotics, and work with microcontroller systems (perhaps 'Physical Computing' might be a better heading than 'Electronics in the table above?).

1.1.2. Previous students and mentors

Asked about the D&T topics currently taught in their schools, they responded as shown in Table 2 below.

Table 2:
KS3 content (previous students and mentors)

	Content taught by previous students (n=31)	Content offered by the school (n=9)
CAD	15	7
Electronics	10	5
Engineering	8	2
Food & Nutrition	20	8
Graphics	14	6
Hospitality and catering	4	2
Mechanisms	8	3
Metals	11	5
Plastics	16	7
Product Design	18	8
Structures	3	4
Textiles within art	4	0
Textiles within D&T	15	6
Timbers	18	8
Other	4	3

The response to the 'Other' question was similar to that from our current cohort (e.g., 'CAD/CAM', 'Isometric and orthographic drawing'). One former student mentioned 'Health and Social Care', and that this is a part of the D&T department in many schools. Another made the interesting comment that 'I *have not taught any other aspects of D&T during my career since graduating the PGCE however I do use my knowledge within the department to help out other teachers and use my limited understand to help out ideas [sic].*'. This seems to suggest a question that is well worth asking; how far ahead are we thinking about a current student's career when planning our PGCE content?

One mentor noted that 'D&T and Food & Nutrition (F&N) are two different dept in school'; which is arguably tangential to the question asked, but, when viewed alongside the current structure of the D&T KS3 National Curriculum and separated GCSE specifications for D&T and F&N, raises its own questions about how teacher training in this area should be organised.

Finally, here, questions arise as to whether the areas mentioned most often by the schools are the ones where we should focus most time in the PGCE or, conversely, whether we should give attention to those less often taught in schools on the grounds that these are important aspects of the national curriculum and GCSE specs in which students are less likely to get support in learning while on placements.

1.2. GCSE courses taught in your school.

The options provided in this section of the survey were based on the range of Key Stage 4 (KS4 14-16 year-olds) qualifications available in England that we know are taught in at least some D&T departments – for this reason we did here explicitly include Art and Design.

1.2.1. Current students and mentors

Here we asked students which KS4 courses they had had the opportunity to teach in their placement. Similarly, we asked the mentors about the range of KS4 courses offered at KS4 to the school's pupils (Table 3).

Table 3:
KS4 courses (current students and mentors)

	KS4 courses taught by PGCE students (n=11)	KS4 courses offered by the school (n=16)
GCSE Design and Technology	5	13
GCSE Engineering	0	1
GCSE Food Preparation and Nutrition	5	14
GCSE Art and Design	1	10
Level 1/2 Engineering	0	7
Level 1/2 Health and Social Care	0	6
Level 1/2 Hospitality and Catering	2	5
Other	0	7

Noting that the students were in their first placement, it is unsurprising (but reassuring) that the majority were being asked to teach the 'core' GCSEs of D&T and F&N. The student teaching within A&D was focussed on textiles work.

The responses to 'Other' from the mentors included a wide range of 'non-GCSE' (that is, vocational) qualifications related to D&T, including Graphic Design, Construction and Child Development, as well as some qualifications more related to A&D including 3D Art and many mentions of Photography.

A question raised for us by this data is whether, in the limited time available to us on a PGCE course, we should be giving a higher profile to vocational courses for 14-16 year-olds related to D&T.

1.2.2. Previous students and mentors

Again, we asked the previous students and mentors about the range of KS4 courses offered at KS4 to the school's pupils (Table 4).

Table 4:
KS4 courses (previous students and mentors)

	KS4 courses taught by previous students (n=31)	KS4 courses offered by previous mentors' schools (n=9)
GCSE Design and Technology	15	8
GCSE Engineering	2	0
GCSE Food Preparation and Nutrition	14	6
GCSE Art and Design	6	1
Level 1/2 Engineering	3	1
Level 1/2 Health and Social Care	3	1
Level 1/2 Hospitality and Catering	3	2
Other	7	4

As expected, the majority of our previous students are teaching D&T and/or F&N at GCSE. The number teaching A&D is noteworthy. The range of 'Other' KS4 courses mentioned is quite interesting (Table 5).

Table 5:
'Other' KS4 courses (previous students and mentors)

KS4 Course	student	school
Level 1/2 Construction	1	2
NCFE Level 1/2 Graphic design	1	
GCSE Photography	2	
Vcert Food and Cookery	1	
IGCSE Cambridge Food and Nutrition	1	
WJEC level 1/2 Constructing the Built Environment	1	
GCSE Design and Technology Textiles		2
GCSE D and T Graphics		1
BTEC Award Art and Design		1
Level 1/2 (vocational) Creative Design and Production		1

Firstly, we note that there is no such thing as a GCSE in either 'D&T Textiles' or 'D&T Graphics', but it is interesting that some schools appear to be, in effect, subverting the spirit of a single-title GCSE in D&T by, presumably, advertising the GCSE to students (and parents) as a single material-focused qualification. One could call this simple honesty as we know that this is the approach that a great many schools take to D&T GCSE, but rather less explicitly.

Secondly, the table indicates the wide range of things that D&T departments have to turn their hands to, albeit at relatively low numbers. As teacher trainers it leads us to ask to what extent we should try to include subject knowledge related to this wide range of vocational courses within the limited time we have with students.

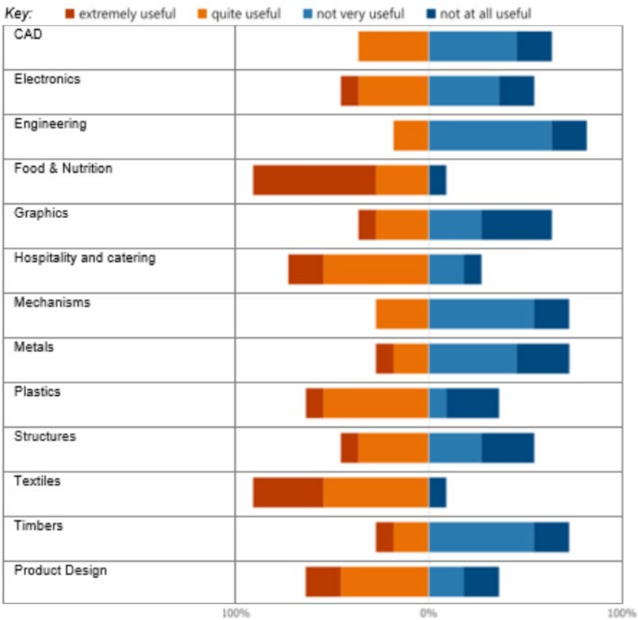
1.3. The 'usefulness' of the teacher training subject knowledge content

The surveys next turned to asking the student teachers and their mentors how well the subject knowledge the students had been exposed to in their PGCE and pre-course Subject Knowledge Enhancement (SKE) courses matched the subject knowledge demands they had met in teaching.

1.3.1. Current students and mentors

Seven out of the Eleven students had completed a SKE course prior to starting the PGCE. Five of these had been totally online, two with a blended course. They were asked which elements of subject knowledge covered as part of their PGCE/SKE have been the most useful in their placement. Their responses are shown in Table 6.

Table 6:
Usefulness of course subject knowledge (current students)



Asked about subject knowledge gaps that they encountered on placement, 8 of the students said they had encountered such gaps and these spread across the full range of D&T content as shown by the word cloud in Figure 1.

Figure 1:
A summary of subject knowledge gaps noted (current students)

Asked about the subject knowledge they had needed to develop on placement they provided a similarly wide range of responses as shown in Figure 2.

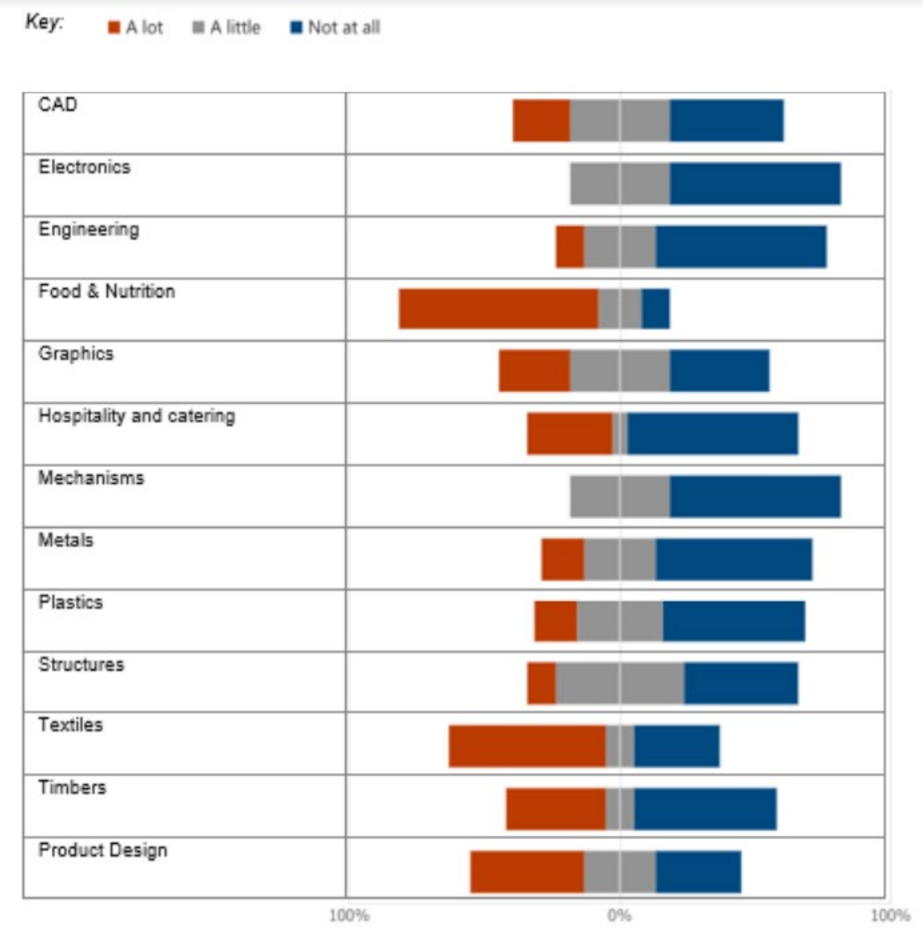
Figure 2:
A summary of subject knowledge developed on placement (current students)

These cloud summaries lack a great deal of precision and also stray well beyond our interest (for this study) in specific subject knowledge. They do however provide an insight into students' concerns towards the start of their first school placement that will be fed into the next round of PGCE course planning. Extracts from two of the longer responses shown below provide some context and seem to us to capture two realities of learning to be a D&T teacher:

> I feel I know a lot more than I thought I did. I haven't struggled to explain things or answer pupils' unexpected questions and have had positive feedback from mentors & SLT regarding my subject knowledge.
>
> It is very hard with Design and Technology as a subject to become a specialist and build knowledge to teach everything at a high level. This makes it naturally much harder to teach all lessons at a higher level and ups the work load compared to other ITT subjects.

The subject mentors were asked which elements of subject knowledge the students had needed to use in this placement. These responses are shown in Table 7.

Table 7:
Subject knowledge used on current placement (current mentors)



Tables 6 and 7 have broadly similar shapes which provides a degree of triangulation in relation to understanding of subject knowledge demand between students and mentors. There is a fairly strong indication in these tables that technical areas of the curriculum (electronics, mechanisms, knowledge of materials, structures) are less in demand. However, we recognise that when the survey was conducted the students were in their first placement and mentors may well have constructed their timetables around areas perceived as less demanding in terms of subject knowledge. It is also the case that the surveys were conducted before the second university-based phase of the course, where there is further significant subject knowledge input. Finally, it is worth noting that, given the proportions of time allocated to university- and school-based training, it is inevitable that schools will need to contribute to trainees' subject development.

Mentors were also asked to detail subject knowledge gaps that they had noted as the trainees started their placement, these are summarised in Figure 3.

Figure 3:
A summary of subject knowledge gaps noted (current mentors)

We also asked mentors to say where they felt the university-based course should place more emphasis. The responses included the following:

Sustainability in D&T

Photography

More Textiles knowledge e.g. sources of fibres and how to use a sewing machine.

There are very few students with practical metal working experience. Few are able to operate centre lathes, milling machines. Most have never done any heat treatment, welding, casting, etc. Some have basic wood working skills but very few are able to produce things like a dovetail joint or operate a wood lathe.

Use of CAM and systems and control

More practical aspect of running practical lessons with students, i.e. how to watch them, where to position themselves in the room, setting short tasks and getting them to be more independent in the lesson. Assigning student specialists to take the pressure off the teacher. Setting extension tasks for more able students.

More graphics

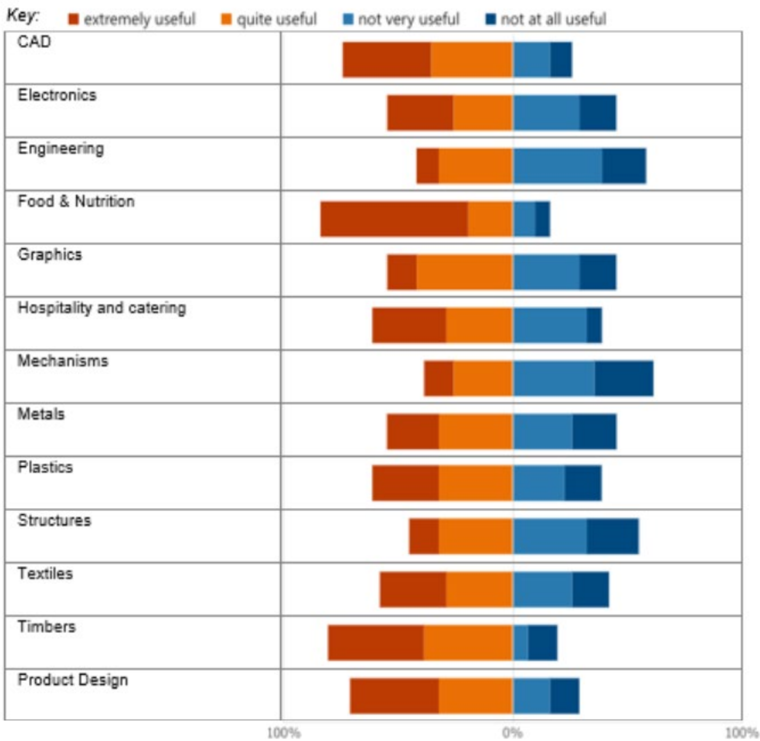
I think this is difficult with the way the SKE course was offered this year as much was delivered remotely and did not cover the same content as previous years. Getting back to hands on delivery would be best. Consider 'delivery of lesson' classes to try and provide an understanding to PGCE students on how to project voice etc.

This is not the place for a detailed response to these (the list is a mix of things we had done with the students, would cover between the two placements and are never likely to achieve with the wide mix of degree backgrounds that PGCE students bring with them). However, we think the significance of this list is that mentors here are demonstrating to us is that there is a gap between their expectations and the course's realistic aspirations given the constraints. This is an opportunity for better communications between the partners in teacher training.

1.3.2. Previous students and mentors

The same questions about subject knowledge were asked of our previous mentors and students. 18 out of the 33 students had completed a Subject Knowledge Enhancement (SKE) course prior to starting the PGCE. Three of these had been totally online, the rest blended. Asked how useful they felt the SKE and PGCE content had been in their teaching posts, they responded as shown in Table 8.

Table 8:
Usefulness of course subject knowledge (previous students)



Asked about subject knowledge gaps that they encountered when they first started teaching, 19 of the students said they had encountered such gaps, and these spread across the full range of

D&T content. When asked about aspects of subject knowledge that they had had the opportunity or need to develop since starting teaching, a range of responses was provided, as summarised below.

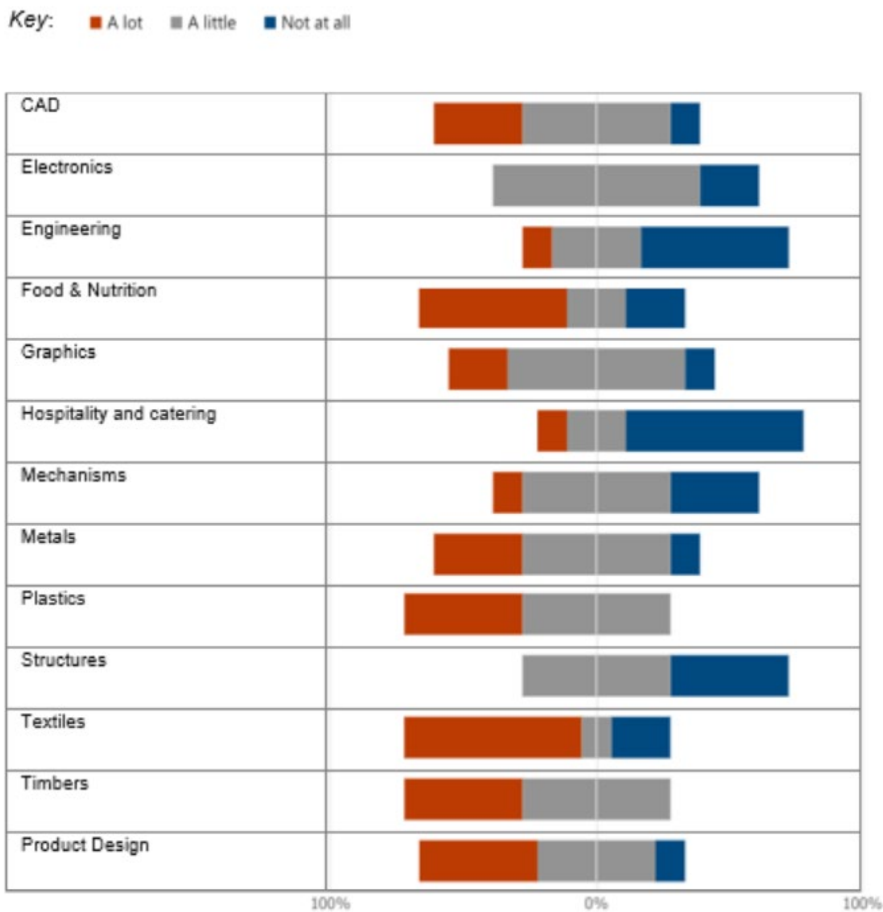
> *Particularly, textiles and food science. Strengthened knowledge on timbers, metals and plastics.*
>
> *One area I did need training on was Marking GCSE NEAs.*
>
> *Electronics CAD RM practical*
>
> *Graphic design, I had to teach myself perspective drawing and use my industry knowledge of adobe illustrator*
>
> *3D printing, laser cutting CAD*
>
> *Maybe the fibres and types of fabrics in textiles.*
>
> *All of food prep and nutrition*
>
> *Health and social care*
>
> *Being a product design specialist I have had to continually develop my subject knowledge in graphic design and food.*
>
> *Timbers hand tools ks4. 3d modelling fusion 360*
>
> *CAD. Using machines such as 3D printer and laser cutter.*
>
> *Food and nutrition*
>
> *CAD, electronics*

Asked about things they felt should have been covered in the PGCE, a list of things very similar to the above emerged, though it was quite heartening to get comments like:

> I feel everything covered gave me more than enough knowledge and confidence to go into teaching and start teaching well. There are some things that maybe weren't covered in detail for example marking assessments and coursework or preparing for parent evenings. However those things you can not really understand and learn from until you actually do it in teaching. So I feel everything covered was more than sufficient.

Once again, the previous subject mentors were asked which elements of subject knowledge the students had needed to use when on placement. These responses are shown in Table 9.

Table 9: Subject knowledge used by students on placement (previous mentors)



The profile here is quite similar to that in Table 7 (current subject mentors), through with a higher profile for Metals and Plastics. Given the small numbers we are working with, we don't think we can read too much into this.

The range of responses to questions about the gaps that students had when starting their placements and what other aspects of subject knowledge they felt should have been covered in the SKE and PGCE were very similar to the responses from current mentors.

1.4. Concluding thoughts

As well as confirming the very wide range of subject knowledge that D&T teachers can be expected to teach – ranging well outside what might usually be considered as core to the subject, the following key aspects of subject knowledge development within a PGCE arise:

- A tension between preparing students for the subject knowledge they will need in a specific placement and preparing them for the wide range of knowledge they could meet when they start teaching.
- A tension between preparing students for the most commonly taught D&T subject areas in schools and introducing them to topics (such as physical computing) that are important parts of the subject yet (for a host of reasons) relatively poorly represented in many schools' curricula.
- A tension between preparing students for the 'core' subjects of D&T and FP&N and also acknowledging the wide range of vocational courses that D&T departments can be required to teach.
- A tension between preparation to teach D&T and to teach FP&N; these areas are, in many schools and increasingly, being taught as separate subjects – and recent work from the Food Teachers' Centre (2023) suggests momentum in this direction.
- The need for strengthened communications between PGCE providers and partner schools about how subject knowledge development can best be shared coherently so as to best serve the needs of not only the PGCE students but also the placement schools.

One of the interesting things that emerged for us from the data was the way that mentors, given the invitation to provide us with feedback, wanted to talk about much more than just subject knowledge. Like any PGCE, we have a programme of mentor training meetings, course reviews, discussion with mentors on school visits and so on, all of which seek to elicit mentors' views. But mentors are busy people, pulled in many directions; it seems that the format of a survey (assuming mentors find time to complete it) provided a bit more time for thought and expression of views. With hindsight this is unsurprising and suggests to us that wider ranging surveys of mentor's views are needed.

More broadly what emerges from the data is the need for more detailed communication between PGCE and subject mentors, allowing for the sharing of views and shared planning of content that leads ultimately to a clearer understanding of the shared responsibility for subject knowledge development.

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Mentoring on Early-Career Technology and Engineering Teachers

Joseph Furse, Utah State University, joseph.furse@usu.edu
Cory Ortiz, University of Alaska Southeast, cortiz10@alaska.edu
Emily Yoshikawa-Ruesch, Utah State University, emily.ruesch@usu.edu
Hannah Lloyd, Utah State University, hannah.lloyd@usu.edu

ABSTRACT

Many researchers in technology and engineering education (TEE) have identified the shortage of TEE teachers as an existential crisis within the discipline. A major component of this crisis is the retention of early-career TEE teachers. The aim of this study was to identify and investigate the impact of current early-career mentoring practices on early-career TEE teachers' sense of belonging, job satisfaction, and expectations to remain in the teaching profession. Data were collected from early-career technology and engineering teachers via an online survey distributed across the United States of America through the Association for Career and Technical Education, the International Technology and Engineering Educators Association, and state-level Career & Technical Education directors. Data were analysed regarding the mentoring opportunities available to early-career TEE teachers, their perceived effectiveness, and the relationship between mentoring and sense of belonging, job satisfaction, and teachers' intentions to remain in the profession.

Keywords: Teacher Retention, Mentoring, Early-Career Teachers, Technology Education, TEE

1. INTRODUCTION

Teacher retention is a critical issue in education as teacher attrition continues to be a significant challenge worldwide (Boyd et al., 2011; Carver-Thomas & Darling-Hammond, 2017; Ronfeldt et al., 2013). High teacher turnover negatively impacts student achievement and school communities overall (Ronfeldt et al., 2013). Understanding the factors that influence teacher retention has become a focus in educational research, especially in the field of Technology and Engineering Education (TEE).

Many studies have examined factors influencing teacher retention, including pay, administrative support, mentoring programs, school climate, and professional development (Boyd et al., 2011; Bullough, 2012; Gilles et al., 2017; Ritz, 2006). Effective mentoring programs may play an important role in supporting incoming teachers as they transition from teacher preparation programs to full-time teaching (Bullough, 2012). Nowhere are effective mentoring programs needed more than among TEE teachers.

The purpose of this study was to investigate the mentoring opportunities available to early-career TEE teachers, and to investigate the relationship between mentoring and job satisfaction, sense of belonging, and persistence intentions among early-career TEE teachers. The following research questions were developed for this study:

What mentoring opportunities are available for early-career TEE teachers?

Which mentoring activities are perceived as most effective by early-career TEE teachers?

How does mentoring impact early-career TEE teachers' sense of belonging, job satisfaction, and persistence intentions?

3. LITERATURE REVIEW

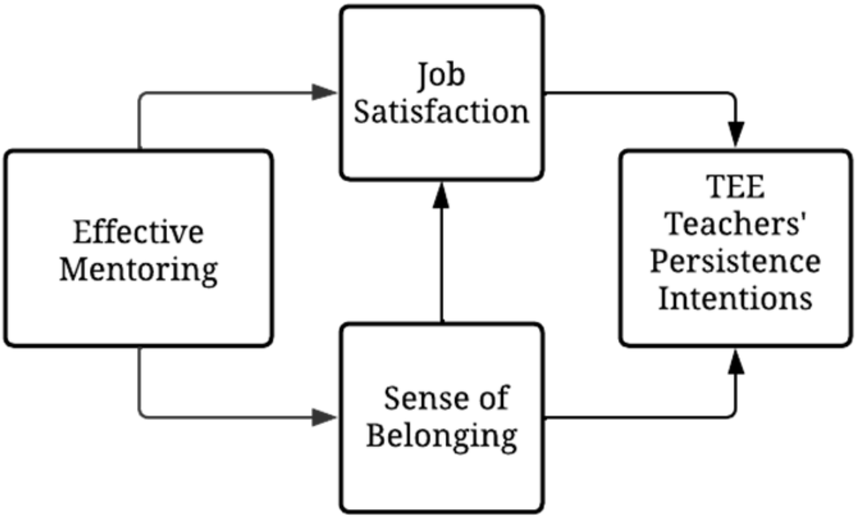
Understanding factors influencing TEE teachers' persistence is crucial to addressing teacher shortages within the profession. Previous research has highlighted the positive impact of mentoring programs among early-career teachers (Gilles et al., 2017; Bullough, 2012). Mentoring programs have been shown to provide guidance, support, and professional development opportunities when implemented effectively. Additionally, mentoring contributes to a sense of belonging and increased job satisfaction by helping novice teachers establish connections within the school community (Hallam et al., 2012).

Sense of belonging has been recognized as a crucial factor in shaping job satisfaction and persistence intentions among new teachers (Ortiz, 2022; Skaalvik & Skaalvik, 2011). When teachers feel a sense of belonging within their school community, it can positively impact their job satisfaction and increase their intention to persist (Ortiz, 2022). Conversely, a lack of belonging may lead to lower job satisfaction and a higher likelihood of considering alternative careers.

Job satisfaction has also been recognized as an important component of early-career teacher retention (Ortiz, 2022; Renbarger & Davis, 2019; Skaalvik & Skaalvik, 2011). Ortiz (2022) found that job satisfaction mediated the relationship between sense of belonging and persistence intentions among TEE teachers. In addition, Renbarger & Davis (2019) found that job satisfaction among teachers was improved with the presence of a mentor.

The conceptual framework used in this study was based on the findings of Ortiz (2022). The present study measured the effect of early-career mentoring as a moderating variable on both job satisfaction and a sense of belonging as shown in Figure 1.

Figure 1.
Conceptual framework for the impact of mentoring on job satisfaction and sense of belonging leading to increased TEE teacher persistence.



Existing literature has illuminated the interrelatedness between mentoring, job satisfaction, sense of belonging, and persistence among teachers, but more research is needed to further understand these relationships among TEE teachers. TEE teachers have unique characteristics, methodologies, and responsibilities compared to teachers from other disciplines such as language arts, mathematics, etc. Existing research has mainly focused on teachers generally and has not accounted for the unique needs of TEE teachers. This study sought to bridge this gap by investigating the relationships between mentorship, job satisfaction, sense of belonging, and persistence intentions among early-career TEE teachers and to identify mentoring opportunities available to early-career TEE teachers in the United States.

4. METHODOLOGY

This study utilized a convenience sample of early-career TEE teachers who responded to an anonymous online survey distributed through the International Technology and Engineering Educators Association (ITEEA), the Association for Career and Technical Educators (ACTE), and state CTE directors. No incentives were offered for participation in this study.

Teachers who were in their first five years of teaching technology and/or engineering (T&E) courses and completed the survey were included in the study. Other demographic information collected included type of licensure, gender, and race.

The survey instrument also incorporated measures of teachers' sense of belonging (adapted from the "Sense of Belonging to School" scale; Roberts, et al., 1995), job satisfaction (adapted from the "Job Satisfaction Survey;" Judge, et al., 1998), and persistence intentions (derived from Sorenson, 2015). These measures are detailed in the dissertation by Ortiz (2022). Examples from each construct are shown in Figure 2. The survey data was analysed using descriptive statistics, correlation, and regression analyses.

Figure 2.
Sample survey items

Sample Sense of Belonging Item

We would like to know about your sense of belonging as a technology and/or engineering teacher. Please indicate the extent to which you agree or disagree with each statement below.

	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
In my job, there is a great deal of cooperative effort among staff members.	○	○	○	○	○	○

Sample Job Satisfaction Item

The following statements address how you feel about your job. Please indicate the extent to which you agree or disagree with each statement below.

	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
I feel satisfied with my present job.	○	○	○	○	○	○

Sample Persistence Intentions Item

Please indicate the extent to which you agree or disagree with the following statements regarding your intentions to remain in your position as a technology and/or engineering teacher.

	Strongly disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly agree
I plan to remain a technology/engineering teacher until I retire.	○	○	○	○	○	○

5. RESULTS

5.1. Sample Description

In total, 293 participants began the survey; however, many prospective participants did not meet the inclusion criteria. In all, 68 participants completed the entire survey and met the inclusion criteria. Of these participants, 31 identified as male, 34 as female, 2 as non-binary, and 1 preferred not to say. For race, ethnicity, and origin, 89.7% of participants identified as White (non-Hispanic), 7.4% as Asian, 4.4% as Hispanic/Latinx/Spanish Origin, and 2.9% as American Indian/Alaska Native, and 1.5% each as Black/African American and Native Hawaiian/Pacific Islander, respectively.

This study included participants with between 1 and 5 years (inclusive of the current year) experience teaching secondary T&E classes. The average years of experience teaching T&E courses was 3.06 years (SD = 1.47). Total years of formal teaching experience, including years taught outside of secondary T&E courses was also collected (M = 9.25, SD = 7.09). 60.29% of the participants taught at the high school level (grades 9-12), while 35.29% taught at the middle school level (grades 6-8). 4.41% taught classes in both grade bands.

Participants were also asked about how they obtained their teaching credentials. 47.1% of participants obtained their credentials via a traditional four-year university teacher preparation program, 41.1% through an alternative route to licensure (ARL) program in which they completed licensure requirements during their first few years of teaching, and 11.8% obtained their credential via an emergency authorization and subsequently completed licensure requirements through an ARL program.

Participants were also asked about their membership in professional educator associations, including major organizations catering to TEE teachers in the United States, with 44.1% indicating membership in the Association for Career & Technical Education (ACTE), 14.7% in the International Technology & Engineering Educators Association, and 17.7% indicated belonging to another organization for professional educators. 42.7% of participants indicated that they did not belong to any professional educator association.

5.2. Availability and impact of mentoring opportunities

One research question in this study was to determine what type of mentoring opportunities exist for early-career TEE teachers. In the survey, participants were asked to select mentoring activities that were available to them as early-career TEE teachers. Table 1 shows the mentoring opportunities teachers in this sample had available to them.

Table 1.
Participant access to early-career mentoring opportunities (N = 68)

Mentoring Opportunity	Definition	f	%
Professional learning community (PLC) – TEE, horizontal	Meeting with a group of other TEE teachers in the same grade band	33	48.5
PLC – TEE, vertical	Meeting with a group of other TEE teachers in different grade levels	14	20.6
PLC – non-TEE	Meeting with a group of other teachers where at least one is from a different content area	24	35.3
Informal mentor – TEE	Meeting with a non-assigned mentor who teaches TEE classes	19	27.9
Informal mentor – non-TEE	Meeting with a non-assigned mentor who does not teach TEE classes	13	19.1
Formal mentor – TEE	Meeting with an assigned mentor who teaches TEE classes	8	11.8
Formal mentor – non-TEE	Meeting with an assigned mentor who does not teach TEE classes	16	23.5
Professional conference attendance	Attending a professional conference for educators	43	63.2
Professional association resources	Access to resources (e.g., curriculum) provided by a professional organization for educators	30	44.1

Participants were also asked to select how often they utilized the mentoring opportunities that were available to them. Table 2 shows how often participants participated in the mentoring opportunities to which they had access.

Table 2. Participant engagement in available mentoring opportunities

Mentoring Opportunity	Never	1-2 times per year	A few times per year	≥ Once per month	≥ Once per week
PLC – TEE, horizontal	0 (0.0%)	8 (24.2%)	9 (27.3%)	11 (33.3%)	5 (15.2%)
PLC – TEE, vertical	1 (6.7%)	3 (20.0%)	2 (13.3%)	8 (53.3%)	0 (0.0%)
PLC – non-TEE	0 (0.0%)	0 (0.0%)	2 (8.3%)	11 (45.8%)	11 (45.8%)
Informal mentor – TEE	1 (5.3%)	4 (21.1%)	6 (31.6%)	3 (15.8%)	5 (26.3%)
Informal mentor – non-TEE	0 (0.0%)	0 (0.0%)	5 (38.5%)	5 (38.5%)	3 (23.1%)
Formal mentor – TEE	0 (0.0%)	2 (25.0%)	0 (0.0%)	2 (25.0%)	4 (50.0%)
Formal mentor – non-TEE	0 (0.0%)	1 (6.3%)	5 (31.3%)	4 (25.0%)	6 (37.5%)

Professional conference attendance	3 (7.0%)	29 (67.4%)	11 (25.6%)	0 (0.0%)	0 (0.0%)
Professional association resources	3 (10.0%)	8 (26.7%)	8 (26.7%)	4 (13.3%)	7 (23.3%)

5.3. Perceived effectiveness of mentoring activities

Pursuant to research question 2, participants were asked to rate the effectiveness of the mentoring opportunities they had access to. Ratings were made on a 6-point Likert scale ranging from Very ineffective (1) to Very Effective (6). Table 3 shows how participants perceived the effectiveness of the mentoring opportunities based on mean rating scores.

Table 3.
Participant rating of mentoring opportunity effectiveness

Mentoring Opportunity	M	SD
PLC – TEE, horizontal	4.7	1.2
PLC – TEE, vertical	4.6	1.3
PLC – non-TEE	3.5	1.6
Informal mentor – TEE	5.3	1.0
Informal mentor – non-TEE	3.9	1.7
Formal mentor – TEE	5.4	0.8
Formal mentor – non-TEE	4.4	1.2
Professional conference attendance	4.7	1.2
Professional association resources	4.3	1.4

5.4. Sense of belonging, job satisfaction, and persistence intentions

The final research question in this study was to identify impacts of mentoring programs on early-career technology and engineering teachers' sense of belonging, job satisfaction, and persistence intentions. Reliability was calculated for each of these three constructs within the survey instrument. For sense of belonging, the reliability of the instrument was found to be good to excellent ($\alpha = .881$). This also held true for job satisfaction ($\alpha = .886$) and persistence intentions ($\alpha = .891$).

Based on survey responses, average scores were calculated for participants' overall sense of belonging ($M = 4.2$, $SD = 1.0$), job satisfaction ($M = 3.8$, $SD = 0.9$) and persistence intentions ($M = 3.8$, $SD = 1.2$). In addition, these scores were disaggregated based on mentoring opportunities participants had available to them, as shown in Table 4.

Table 4.
Average job satisfaction, sense of belonging, and persistence intention scores disaggregated by mentoring opportunities

Mentoring Opportunity	**Job Satisfaction**		**Sense of Belonging**		**Persistence Intentions**	
	M	SD	M	SD	M	SD
PLC – TEE, horizontal	4.2	0.3	4.3	0.9	3.2	0.4
PLC – TEE, vertical	4.3	0.3	4.5	0.9	3.3	0.5
PLC – non-TEE	4.2	0.3	4.2	1.1	3.3	0.5
Informal Mentor – TEE	4.2	0.3	4.4	0.8	3.2	0.5
Informal Mentor – non-TEE	4.3	0.3	4.4	0.8	3.2	0.5
Formal Mentor – TEE	4.2	0.3	4.4	0.6	3.3	0.5
Formal Mentor – non-TEE	4.2	0.4	4.7	0.7	3.1	0.5
Professional conference attendance	3.9	0.9	4.2	0.9	3.8	1.2
Professional association resources	4.0	0.8	4.0	1.0	3.9	1.1

In addition, six participants did not mark any of the mentoring opportunities as available to them. Mean job satisfaction, sense of belonging, and persistence intention scores of these participants are shown in Table 5.

Table 5.
Job satisfaction, sense of belonging, and persistence intentions for participants marking no mentoring opportunity availability (n = 6)

	M	**SD**
Job Satisfaction	3.2	0.7
Belonging	4.2	0.9
Persistence Intentions	3.0	1.5

Finally, regression analysis was conducted for sense of belonging, job satisfaction and persistence intentions to identify which variables were statistically significant predictors of these constructs, as shown in Tables 6, 7, and 8, respectively.

Table 6.
Summary of multiple regression analysis for variables predicting sense of belonging (N = 68)

Effect on Sense of Belonging	**B**	**SE B**	**95% CI**		**t**	**p**
			LL	UL		
Job Satisfaction	0.21	0.12	-0.03	0.45	1.702	0.950

Informal mentor – non-TEE	0.65	0.25	0.15	1.15	2.531	0.014

Note. Adjusted R-Squared = .13; F-statistic: 5.02 on 2 and 52 DF, p-value: 0.010; CI = confidence interval LL = lower limit; UL = upper limit.

Table 7.
Summary of multiple regression analysis for variables predicting job satisfaction (N = 68)

Effect on Job Satisfaction	**B**	**SE B**	**95% CI**		**t**	**p**
			LL	UL		
Sense of Belonging	0.27	0.13	0.01	0.52	2.03	0.048
PLC – non-TEE	-0.57	0.25	-1.05	-0.09	-2.31	0.025

Note. Adjusted R-Squared = .11; F-statistic: 4.454 on 2 and 52 DF, p-value: 0.016; CI = confidence interval LL = lower limit; UL = upper limit.

Table 8.
Summary of multiple regression analysis for variables predicting persistence intentions (N = 68)

Effect on Persistence Intentions	**B**	**SE B**	**95% CI**		**t**	**p**
			LL	**UL**		
Job Satisfaction	0.772	0.133	0.51	1.03	5.811	<0.001
Sense of Belonging	0.302	0.136	0.04	0.57	2.231	0.030
ACTE Membership	0.563	0.236	0.10	0.57	2.389	0.021

Note. Adjusted R-Squared = .487; F-statistic: 18.12 on 3 and 51 DF, p-value <.001; CI = confidence interval LL = lower limit; UL = upper limit.

As shown in Tables 6-8, statistically significant regression models were identified for sense of belonging, job satisfaction, and persistence intentions. With job satisfaction as an outcome, the model using sense of belonging and the availability of a non-assigned (informal) mentor who did not teach TEE classes as predictors accounted for 13% of the variance with the mentor variable being statistically significant.

With job satisfaction as the outcome and sense of belonging and the availability of a non-TEE professional learning community as the predictor, the model accounted for 11% of the variance with both variables being statistically significant predictors. For teachers' persistence intentions, the model predicted 48.7% of the variance, with job satisfaction, sense of belonging and membership in ACTE as statistically significant predictor variables.

6. DISCUSSION

The analyses outlined above provided several insights about the impact of mentoring on early-career technology and engineering teachers. First, it is clear that many different opportunities to participate in mentoring activities exist for these teachers; however, some tend to be more commonly available than others (see Table 1). For example, most participants reported that attending professional conferences was an available option for them, while nearly half also reported having access to resources produced by professional organizations, such as curriculum. Nearly half of respondents reported that a professional learning community (PLC) of other technology and engineering teachers in the same grade band was available, and more than a third of participants reported that they had access to a PLC consisting of teachers from different content areas. Conversely, fewer teachers reported that they had access to either a formal or informal mentor, whether in or out of their content area.

The apparent lack of availability of individual mentors among these participants is concerning since, when participants were asked to identify which mentoring opportunities they felt were most effective (see Table 3), having an assigned mentor within their own content area, was perceived as the most effective support out of all of the mentoring opportunities investigated in this study. Formal mentors were rated more highly than informal mentors, and mentors in the same content area were rated as more effective than those outside technology and engineering education. In addition, attendance at professional conferences, professional learning communities consisting of teachers in the same content area (whether in the same or different grade bands), and resources provided by professional educator associations were also perceived as more effective supports.

Curiously, while participants tended to have strong opinions about which mentoring opportunities were most effective in supporting them as early-career technology and engineering teachers, these did not necessarily align with findings relating the availability of mentoring opportunities with participants actual scores on measures of sense of belonging, job satisfaction, and persistence intentions. As shown in Table 4, mean scores in all three constructs were fairly consistent across different mentoring opportunities with only a few exceptions (e.g., participants who were involved in professional associations through conferences or resources scored somewhat higher on persistence intentions). However, when participants who noted no availability of any of the mentoring opportunities, mean scores in job satisfaction were notably lower.

This apparent disconnect between participants perception of the effectiveness of different interventions and the actual relationship with their sense of belonging, job satisfaction, and persistence intentions was further borne out in the regression analysis. None of the highest-rated mentoring opportunities emerged as statistically significant predictors in the regression models for any of the three constructs, while some mentoring activities that were rated lower by the participants (e.g., non-TEE PLCs) were statistically significant predictors. There are some possibilities which could help explain this disconnect. First, obtaining a sufficient sample size for a robust regression analysis was a challenge despite the efforts undertaken by the researchers to reach many early-career TEE teachers across the United States. This could have resulted in data that was biased due to the composition of the sample (notably, the unexpectedly high percentage of female participants). Second, the few minutes taken to fill out an online survey may not have afforded time for participants to recall situations where they were effectively mentored through all the activities presented in the survey.

Despite challenges, the regression analysis did offer some support for the conceptual framework chosen for this study. At least some mentoring activities did support teachers' sense of belonging and job satisfaction. Job satisfaction was also predicted in part by sense of belonging, and both job satisfaction and sense of belonging were found to be significant predictors of persistence intentions. This suggests that, challenges notwithstanding, this research is on the right track in terms of investigating how mentoring can be an effective tool to retain early-career technology and engineering teachers.

7. CONCLUSIONS

The retention of early-career technology and engineering teachers is a major issue within technology and engineering education, both within the United States and elsewhere. The purpose of this study was to investigate the impact of mentoring on the sense of belonging, job satisfaction, and persistence intentions of early-career TEE teachers, with the hope that this research will inform further research in this area as well as better practices at the national, state, and local level with respect to programs targeted to retain technology and engineering teachers beyond the early-career phase. Several implications for further research and best practices emerged from this research.

7.1. Implications for further research

One of the challenges in conducting this study was obtaining a large sample for analysis. Further quantitative research in this area should perhaps take a different approach to sampling procedures, such as narrowing the focus to an individual state/province or collecting data at professional conferences. Online surveys are easily passed over in the busy life of a teacher, particularly early in their career. Obtaining a larger sample size with better data collection strategies would allow for more reliable findings regarding best-practices.

Further qualitative or mixed-methods research could focus on narrowing down to specific mentoring practices that are found to be effective, and identifying the characteristics that make these practices effective. For example, studies should be conducted which investigate what types of interactions between an individual mentor and early-career TEE teacher are most helpful in supporting the novice teacher, or what characteristics in a mentor are most impactful. This could also be done with respect to professional learning communities, beyond just looking at PLC composition but how PLCs among technology and engineering teachers can best be structured and implemented to support teachers early in their careers. Finally, research should be conducted to identify what supports offered by professional associations, both at and outside of conferences, are most effective in encouraging a sense of belonging.

6.2 Implications for practice

Some findings in this study can be of immediate use to administrators who oversee the development of early-career technology and engineering education teachers, such as district-level Career & Technical Education directors, individual building administrators, and stakeholders at the state level such as content-area specialists. First, it appears that early-career technology and engineering teachers strongly perceive that having an assigned mentor who teaches in their content area is the most effective support for their development. While many technology and engineering teachers in the United States are the only teacher in their school who teaches this content, district-level administrators could easily implement a program assigning another teacher from a nearby school who teaches the same content as a mentor for an early-career teacher. It is critical that early-career technology and engineering teachers have access to at least one individual mentor. A similar approach could hold true for implementing content-area PLCs that bring technology and engineering teachers together regularly from across an entire school district, or a portion thereof to share pedagogical strategies and curriculum.

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The Initial Findings of the Healthy Lifestyles Project: A Practical Design and Technology Cooking and Nutrition Programme for Primary Schools

Suzzanne Gomersall, Nottingham Trent University, suzanne.gomersall@ntu.ac.uk

ABSTRACT

Childhood obesity has reached epidemic levels in developed countries, with those who live in lower socio-economic groups twice as likely to be obese (Davies, 2019). This paper will report the findings and analysis of the first 4 years of a six-year longitudinal study into the impact of the Healthy Lifestyles Project (HLSP), which is currently being piloted as part of the D&T curriculum in a school in an area of high deprivation. The HLSP aims to develop children's practical cooking and nutrition skills, knowledge and understanding, enabling them to choose, prepare and cook healthy ingredients to feed themselves and their families, helping to change their attitudes and perceptions towards choosing a healthier lifestyle. By drawing on the experience of head chef at the Adopt a School Trust, the HLSP has been designed to provide a programme for staff, children and parents which aims to make a positive contribution to tackling children's health in the UK and beyond.

There are four key features of the HLSP:

1. Regular termly cooking and nutrition lessons
2. Termly support for parents
3. Opportunities for children to plant, grow and eat their own fruit and vegetables in the school grounds
4. Teaching resources for before, during and after the practical food sessions

Theory and research suggest that when looking at changing behaviour, interventions that have several aims and approaches are more successful. Therefore, when designing the HLSP, a multi-pronged approach was required to address attitudes and behaviours by tackling some of the physiological, environmental and social issues behind childhood obesity. One theoretical framework that the HLSP aligns to closely is Social-Ecological Model (SEM), based on Bronfenbrenner's (1979) ecological model. Preliminary evaluations on the impact the project have been made across the five aspects of the SEM theoretical framework: individual, inter-personal, organisational, community and policies, laws & other cultures.

Keywords: obesity, cooking, nutrition, healthy, lifestyle

1. INTRODUCTION

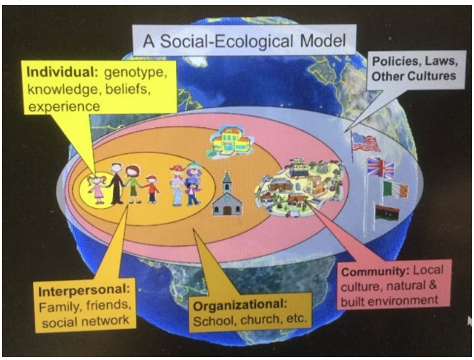
Childhood obesity has reached epidemic levels in developed countries, (Davies, 2019; House of Commons Health Committee, 2018), which is more likely to lead to higher adult obesity levels, leading to potentially serious health consequences (World Health Organisation (WHO), 2018; Public Health England (PHE), 2017), such as heart disease and diabetes. Dimbleby and Vincent, (2013) suggest that a lack of knowledge and understanding of healthy eating and how to cook is a possible cause. Currently, in 75% of schools the teaching and learning of practical cooking skills is absent (Ofsted, 2020), despite this being part of the statutory Design and Technology Programmes of Study within the English National Curriculum (DfE, 2014). If we continue to marginalise cooking in schools, we "run the risk of another generation being unable to pass on these essential life skills to their own children" (Dimbleby and Vincent, 2013, p 32).

The Healthy Lifestyles Project (HLSP) has been designed to be delivered for the six years that the sample group of 32 children attend primary school (age 5-11). The design of the HLSP is explained in more detail in my recently published chapter (Gomersall, 2023). This longitudinal study, which is the basis of a PhD, will evaluate the impact of the project, to see if providing children termly practical cooking and nutrition sessions, along with support and information for teachers and parents would change their attitudes and behaviours towards healthy eating and ultimately, reduce the number of children who become overweight or obese (Gomersall, 2023). This paper focuses on the initial findings of the HLSP over the first 4 years of the six-year study.

2. METHODOLOGY

Theory and research suggest that when attempting to change behaviour, interventions that have several aims and approaches are more successful (Glanz (nd), Gregson, 2001). Therefore, when designing the HLSP, a multi-pronged approach was required to address attitudes and behaviours. One theoretical framework that the HLSP aligns to closely is the Social-Ecological Model (SEM) (figure1).

Figure 1
Image of the Social-Ecological Model (from: Sammons, P. and Bowler, M., 2020)

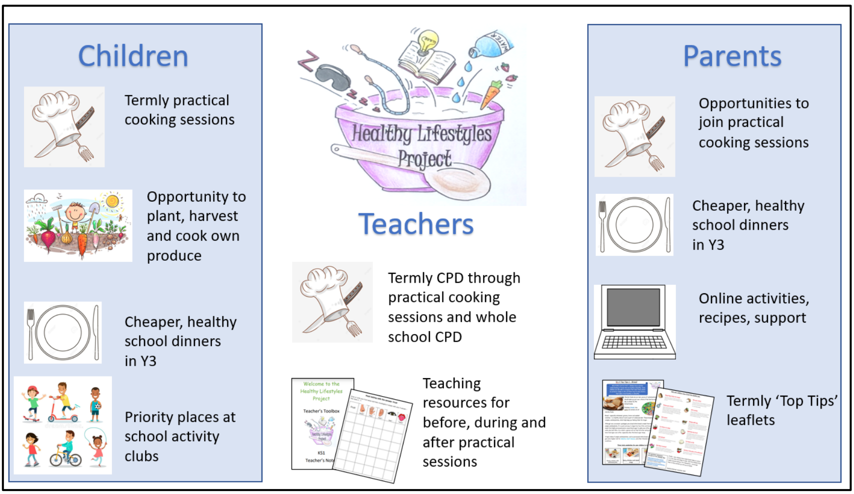


The SEM focuses around behavioural changes by self, interpersonal, organisational, community and public policy (Bronfenbrenner, 1979). Working with the school (organisation), parents (community) and the children (individual/interpersonal) gives the project a strong theoretical framework to influence public policy around cooking and nutrition education in primary schools. The second framework the projects aligns to is Self-Determination Theory (SDT) (Ryan and Deci, 2017) by aiming to meet the basic psychological needs of autonomy, competence and relatedness to lead to an improvement in children's development, enjoyment and motivation.

To create a multi-pronged approach (figure 2), the HLSP drew on:

- Design and technology (D&T) pedagogy of teaching the knowledge, skills and understanding through DMEAs (Design, Make and Evaluate Assignments), FTs (Focused Tasks) and IEAs (Investigative and Evaluative Activities), and consideration of the six principles (functionality, purpose, user, design decisions, authenticity and innovation);
- Both SEM and SDT theoretical frameworks
- Design theory and practice to enable children to create meaningful healthy dishes for the identified consumers, as well as for society at large.

Figure 2
The multi-pronged approach of the HLSP (from: Gomersall, S., 2023)



As triangulation of data is important to increase the validity of results (Naughton et al, 2010; Gomm, 2008), several methods have been used across all three participant groups. Having triangulated the date from food diaries, questionnaires and interviews, themes linked to changes in behaviour and attitudes, and development of D&T skills, knowledge and understanding, were identified. Pseudonyms has been used to protect the identification of any of the participants.

3. RESULTS AND DISCUSSION

3.1. Children

By triangulating the data, results suggest that children enjoy cooking (97%), and 79% are preparing and cooking meals at home. Dishes appear to have become more healthy, varied and complex, with around two thirds of children having made salads, pasta dishes and healthy sandwiches. The dishes taught at school are mainly savoury, to align with the D&T programmes of study (PoS) (DfE, GB, 2013). However, results from the children's questionnaire shows that cakes and biscuits remain the most commonly made food at home (figure 3).

Figure 3.
Comparative data from the children's surveys

Which of the following have you made before?	**Oct 18**	**July 22**
Healthy sandwich	43%	72%
Salad	39%	66%
Bread	15%	55%
Smoothie	35%	41%
Pasta dish	15%	59%
Cakes & biscuits	78%	90%

The HLSP sessions are designed to progressively teach both the content of the D&T PoS and the British Nutrition Foundation core skills (PHE, 2015). Through observations, the children's confidence has improved across all core competencies, especially following a recipe, using a sharp knife and a heat source, many of which the children feel they can do independently (figure 4).

Figure 4.
*Comparative data of children's responses to skills they felt they couldn't do yet. *Only KS1 skills have been captured as data wasn't collected in 2021, 2022 due to Covid*

BNF Core Skill KS1	**I can't do this independently yet:**	
	Oct 2018	**Sept 2020***
Spreading	15%	3%
Peeling	28%	6%
Snipping	46%	16%
Weighing ingredients	35%	3%
Following a recipe	50%	16%
Using a sharp knife	76%	34%
Using a saucepan	89%	44%
Using a kettle	89%	50%

Children's increased confidence was also demonstrated in the group interviews, where many requested to learn to cook a 'proper meal like pasta or a roast' next.

It has been noted at both school and home that children are demonstrating better knowledge and understanding of the principles of a healthy and varied diet, with comments such as: "If you eat stuff that's unhealthy it's not good for your body" and "Too much sugar rots your teeth." One child showed an awareness of the impact it may have on life expectancy:

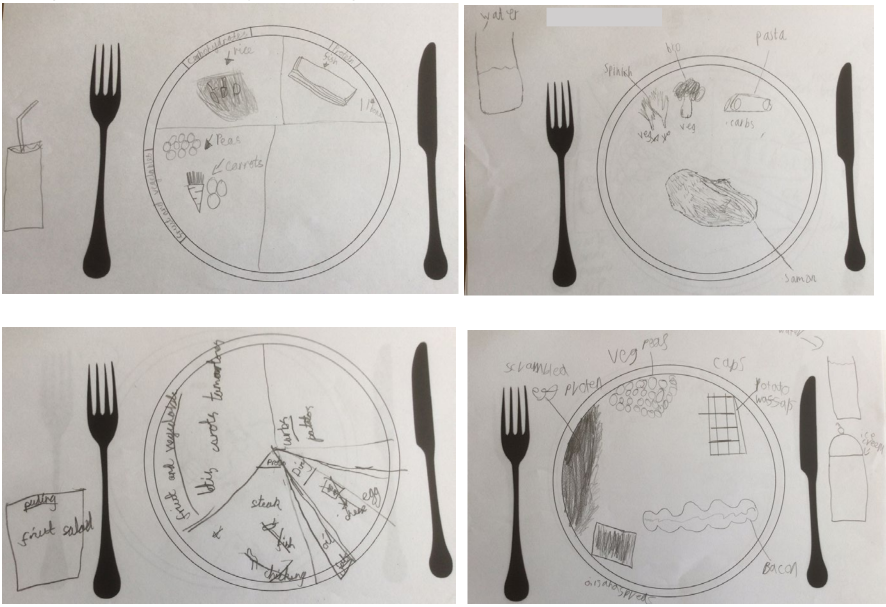
> If we eat too much food with lots of sugar and fat in when we get older, we will die a little bit earlier but if you're healthy you will die a little bit later.

Children also referenced both the Eatwell Guide (PHE, 2018) and traffic light packaging in the group interviews, with one child stating:

> I've been checking (with my mum) how much stuff are (on the wrappers) and I've been eating more healthy stuff. If it's green it's good, if it's amber it's not as good and if its red it's not good for you.

All children were able to design a balanced meal, with many considering the food groups and portion sizes from the Eatwell Guide (see fig 5), selecting only water or milk to drink, justifying their choices, by saying: 'to hydrate you' or 'make your bones strong'. 38% of the children split their plate into food groups, with some children considering portion sizes, knowing they needed a lot of some food groups, and less of others.

Figure 5
Examples of children healthy meal designs



3.2. Teachers

The school's D&T lead suggested that through the HLSP's collaborative and multi-pronged approach, children and their families were demonstrating positive attitude and behavioural changes towards leading a healthier lifestyle.

> I think the willingness to try healthier options, the confidence to cook healthier options and the enthusiasm to go home and bring that to their families…..it's because it's the whole community involved. It's through school, through the pupils, then going home and it's that whole four-way process, isn't it?

A key aspect of the SEM (Bronfenbrener,1979; Sammons and Bowler, 2020) is how behavioural change is linked to the connections across several groups. Only so much can be achieved in isolation by any one of these groups, whether it be school, home or individually. Because most meals are bought, prepared and eaten in the family home, even lunch during the school day (School Food Trust, 2019), the success of this project, therefore, is not just changing the beliefs and attitudes of the children, but the whole family.

Teachers have witnessed the children acting as conduits for this transfer of knowledge, through overheard conversations and information shared via the home-school learning portal, Seesaw:

> I know that they've spoken to parents about it and…… we've had photos on Seesaw….. they've always been talking about healthier things that they have cooked.

> We saw in the soup session that they're aware they need to make healthy choices. They were talking about seasonality, food miles, nutrition and the Eatwell guide.

Completing the annual 7-day food diary has helped bring food choices into the fore, with the D&T lead stating:

> I think…. parents having to help us with [the food diaries]….is having a big impact because parents are the ones making the choices on the meals and the children can influence parents, but the parents ultimately are the ones that are going to make those choices.

Alongside an increase in knowledge and understanding, children's greater confidence and competence during practical sessions was also observed, with one year 4 teacher stating:

> …it's quite clear, they've developed an awful lot. When I think back to the first time that I saw them…..this time there's a wide variety of skills that were immediately obvious, particularly the cutting, using the claw or bridge method.

This supports the children's judgement in their 2020 survey (see fig 4), where two thirds of them felt confident and safe using a sharp knife independently.

There have also been changes to school policy and practice to align with the HLSP, by including a food unit for every year group in the school's updated D&T long term plan. The role of the school gardener has also changed, from supporting the science curriculum previously, to solely focusing on the food curriculum, by planting, growing and harvesting produce to use in certain dishes with whole classes, rather than groupwork. Another key change has been the introduction of savoury foods, such as bagels, bread sticks and crackers, to replace the biscuits being offered to children in the morning, in case they'd missed breakfast.

However, despite this multi-pronged approach and evidence suggesting that HLSP children are developing their skills, knowledge and understanding, the D&T lead acknowledges that knowing and doing are two different things.

> I think there's a difference between being aware and knowing … what a healthy meal would look like, and … the practical choosing of that, but I feel they … do know what a healthier lifestyle is, what is the healthier option … but just like adults, I'm not sure that all of them are making those choices, but they are aware.

3.3. Parents

Comments on the parent questionnaire show an awareness of the benefits of collaboration between school and home:

> Schools and home working as a team is the best way.
>
> It's good initiative for children to learn about healthy eating. School encouragement is more effective than family encouragement and this programme will help this process.

100% of parents hold positive views about the project and the impact they feel it has had at home, both on themselves and their child. They felt sure that behaviour, awareness and choice were being changed and were grateful to be involved.

> Healthy lifestyle is definitely important to us however it means giving up lots of things e.g. junk food… it's a challenge but more exciting is receiving guidance from your child of what's better, due to school practice, gives us a better grounds to carry on.
>
> I believe this is an excellent idea. Habits and choices formed in childhood influence choices made as an adult. If children are taught how to cook they will not need to rely on pre-prepared meals…as they will have the skills they need to cook from fresh.

When considering their awareness of the risk of obesity to their child, 70% of parents ticked the highest category (5-very aware) compared to 47% at the start of the project. Research suggests (Coveney, 2004; Rudolph, 2009; Ruiter et al, 2020) that by raising awareness with parents of whether their child's weight sits within a healthy category, action is more likely to follow, such as making healthier food choices, or reducing portion sizes, with parents referring to changes made such as, "As a family we've started eating healthier foods and trying to cut out the sugary foods" and "I consider my child's weight more".

Evidence in both the parent surveys and food diaries suggests that parents are being influenced to make healthier choices through information shared by the children as a result of the taught sessions, and through termly 'Top Tips' leaflets, such as engaging with the Eatwell Guide, which has increased from 26% of parents stating the Eatwell Guide influenced their food choices 'all' or 'a lot' of the time, at the beginning of the project, compared to 44% now. Another example is an understanding and a use of the traffic light system on food packaging. Additionally, 90% of parents now feel they have 'very good' or 'good' awareness of healthy food choices, compared to 75% at the start.

> HLSP has had a good impact thinking about healthy foods try new veg.
>
> I like that Peter has learnt about the traffic light system on food packaging. It's something that I look at a lot myself now.
>
> I'm also more aware of healthier choices and the impact it has on family.

This was echoed by parents who said, "It [the food diary] is really helpful and reminding us to eat healthy food, especially to encourage Kinga every time to eat healthily and fill up the charts." Current information shows an improving picture with most children eating a balanced home-made dinner most days.

As part of the HLSP, children are taught about the benefits of consuming local and seasonal produce (see fig.2) as well as design vegetable gardens, then plant, grow, harvest, prepare, cook and consume their own produce. Connecting children with the food on their plate is extremely powerful as children are more likely to eat fruit and vegetables if they have grown them themselves (Green and Duhn, 2015). To encourage the 'grow your own' habit at home, tomato plants grown from seed at school were sent home. According to the parent survey, the number doing this has increased by 50%, from 10 families to 15. This aligns with both theoretical frameworks as it considers interpersonal, school and community (SEM) and also competence and relatedness (SDT): "Yes, we grow green beans, tomatoes, potatoes, pumpkin, courgette. Adrian helps plant them and water them," with some utilising their wider families, "no, as we don't have the space but we would like to but Paul helps grow tomatoes & strawberries in his grandad's garden," and "Grandparents grow tomatoes and potatoes which Sonia usually goes and helps with".

Encouraging children to cook at home is paramount to achieving autonomy, competence and relatedness around cooking and nutrition (Ryan and Deci, 2017), which could lead to an improvement in the children's understanding and pleasure of preparing and enjoying healthy food. Therefore, an increase in the children either asking or being asked to help in food preparation at home, would demonstrate another positive impact.

Parents reported a rise in the number of children asking to help in the kitchen; "It has helped as he wants and enjoys preparing foods now," with 62% helping at least once a week now, compared to 50% at the start. When asked, the majority of children (79%) indicated that they cook at home either with a family member or increasingly on their own. Parents asking their children to help more had risen, from 15% at the start, to 24% asking their children to help prepare meals at least 3 times a week, even in busy households:

> Due to work/busy family life we don't always have the time to cook tea together but when we do my son will help to prepare.

The nature of the cooking has got more complex, with children mentioning helping with various tasks, from chopping vegetables for a spaghetti Bolognese, preparing their own food, to cooking hot food with parental supervision. During lockdown, several children posted pictures of themselves cooking family meals on the school's online platform (See-saw, 2020).

> Jade really enjoyed learning about healthy eating, new food and started to become interested in helping to cook,

One of the biggest changes parents noticed was their children's willingness to try different foods.

> My child used to be a very fussy eater. This year he's tried a lot of new foods at school and continues to eat them at home. This has made his diet far healthier and less repetitive.

> It's made Iqbal much more likely to try new foods. He's more interested in preparing food and thinks at times about his choices.

However, for some children, change is not easy, with some parents noting:

> We still have struggles trying to get him to try new foods but since starting the project there's a massive improvement.
>
> Although Lucy doesn't like the healthy options she's now started to eat/try more foods such as chicken.
>
> It made my child think more about what he's eating but he still makes poor choices.

When comparing food diary data, children appear to be consuming less sugary snacks and for many children, fruit is regularly being chosen/given as a snack. This may be down to parents' purchasing choices, e.g., "I am trying to improve snacks the children are eating," but also children's change in behaviour, with one comment on the parent survey stating: "Tom asks if some foods are healthy & likes to tell us when he's chosen a healthy snack".

As part of government policy, children between the ages of 3-7 are provided with a daily free piece of fruit during the school day (DfE, 2023). The aim of this policy is for snacking on fruit to become a positive habit, as well as contributing to the consumption of the recommended 5 portions of fruit and vegetables a day. This has been supported by multiple comments from the parents' surveys, such as: "Lily is more open to trying new fruit and veg and will often choose fruit/veg for a snack".

However, just like the D&T lead, parents remain tentative that acquiring the skills, knowledge and understanding around healthier lifestyles, is not enough to guarantee healthy choices;

> Every time they do or prepare something at school Ishma liked it and is excited and motivated. But four or five days a week he wants to eat McDonald's and sweets every day.
>
> It made my child think more about what he is eating but he still makes poor choices.

4. CONCLUSION

By utilising the two theoretical frameworks and drawing on best D&T practice and design theory, these results suggest that by engaging with regular practical cooking and nutrition sessions at school through the HLSP, the children have developed their interest, confidence and competence across many aspects of food and nutrition. Through successful collaboration between the school, the children and their families, it appears that the HLSP has had a positive effect on changing behaviour and attitudes towards making healthier food choices, enjoying preparing, cooking and consuming healthy meals, not just for the children, but their families too.

In July 2024, the final data will be gathered, and the children's BMI will be compared to the local and national data collated as part of the National Child's Measurement Programme, to see if there has been any impact on obesity rates. Together with the qualitative data collected, this helps increase the validity of the research, meaning, if successful, achieving the same results with the HLSP should be reproducible. The aim is to roll out the HLSP across all primary schools, enabling it to be meaningful to society at large, not just the families of the pilot school.

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"If D&T wasn't so easy, I wouldn't be so good at it": Nonverbal Ability and Confidence.

Alexander Augustus Greenhalgh, The University of Cambridge, art@alexanderaugustus.com

ABSTRACT

At the heart of this paper is a belief that the English education system enacts systemic discrimination against nonverbally intelligent students by teaching and assessing non-academic subjects via academic means. This paper presents action research that *focuses on students with a nonverbal bias, attempting to boost their self-efficacy (Bandura et al., 1999), self-concept (Bong & Clark, 1999), and discusses how these may be hurt by current D&T assessments.* The study examines the comparative perception of intelligence levels needed to succeed in school subjects, alongside the types of intelligences assessed within English educational policy.

To boost intelligences specific to design, this research took a two-pronged approach; verbally promoting high-attaining students and presenting their outstanding book work in the spirit of Gardner's Multiple Intelligence theory (Gardner, 2006), and testing for "eductive" problem-solving intelligences (Raven et al., 1994) at the beginning of each class in a 6-week Scheme of Work with Raven's Progressive Matrices (RPM), logged publicly on a leaderboard in the classroom. The results reveal a positive shift in whole-class perceptions of intelligence needed for D&T, and increased confidence levels among students on the leaderboards, alongside decreased confidence levels of those not on the leaderboards. The study acknowledges limitations in the methodology, particularly an overemphasis on RPM, which subjugated other aspects of intelligence in design, and my own inadvertent acculturation into the quantitative testing culture.

The conclusion acknowledges failures in the research, yet emphasises the need for a cultural shift in English state schools to recognise and respect the non-academic intelligences required to succeed in creative fields like D&T. It highlights the inadvertent discrimination against nonverbally intelligent students due to the dominance of academic culture and advocates for a more tailored approach to D&T assessment which better reflects abilities used in real-world design industries.

Keywords: Design and Technology Education, Self-efficacy in Design and Technology Education, Self-concept in Design and Technology Education, Nonverbal Intelligence, Nonverbal ability discrimination.

1. INTRODUCTION

During my teacher training placements, I became aware that highly capable teachers and students in the Design and Technology (D&T) department considered themselves unintelligent due to a lack of literacy, working memory or low attainment in academic subjects such as English, mathematics or sciences – this is despite being highly adept with their analytical problem-solving, draughtsmanship and manufacturing abilities. Furthermore, I was sceptical that the D&T curriculum was an effective way of accessing many of the abilities used in the design industry due to the preoccupation with memory recall and literacy in coursework and exams. These thoughts formed the rationale for this action research, in which I aimed to identify, assess, and celebrate design-specific intelligences to enhance the confidence of students exhibiting these forms of intelligence.

This paper will critically discuss the value and assessment of intelligence types in schools referencing prominent psychologists such as Spearman (Davis et al., 2011) and Gardner (2006). It will then critically discuss self-efficacy and self-concept, referencing esteemed psychologist Bandura (1999). It will then discuss my action research, consisting of a series of nonverbal intelligence tests accompanied by a public leaderboard. Throughout this paper, I will intersperse discussion of English educational policy and reflections on my own experiences in English state coeducational secondary schools as a teacher of D&T.

I propose that the cultural understanding of intelligence in English state schools is predisposed towards verbally biased students, and has led to the denigration of non-academic subjects. I conclude that my intervention positively shifted perceptions of intelligence in my D&T class and boosted the confidence levels of targeted students. However, major limitations include the overemphasis of "eductive intelligence" (Gardner, 2006) with the leaderboard, ethical considerations linked to this, and my inadvertent acculturation into quantitative testing in creative fields.

8. LITERATURE REVIEW

8.1 What do schools consider intelligence?

In my teacher training school placements, I found that many students who excelled in D&T did not consider themselves equally as intelligent as students who achieved similar grades in subjects such as mathematics, the sciences, or English. During an interview, one student commented, "It's not that I thought I wasn't intelligent, I just thought there were people in that room who were more intelligent than me." When questioned further, they replied, "Mainly because I know them in a lot of other subjects. Like there's loads of them in my maths class […] I'm not great at maths." Despite being one of the top-performing students in D&T class, they felt inferior due to their grades in mathematics. This aligns with a key debate within the field of educational psychology; whether individuals have a general intelligence which determines their intellectual capacities across all subjects, or whether there are different types of intelligences which determine different aptitudes for different tasks (Davis et al., 2011). Cultural notions of intelligence can shed light on this.

Modern-day intelligence tests were developed from the work of French psychologist Alfred Binet, who aimed to identify school children with special educational needs in the early 1900s, and English psychologist Charles Spearman, who attempted to develop a measure of general intelligence, or “g” (Davis et al., 2011). The work of these two catalysed a contemporary understanding of intelligence as being a single general measure (Davis et al., 2011). However, in recent decades there have been many challenges to this notion, perhaps the best known is Gardner’s theory of Multiple Intelligences (MI), which asserts that the ability to demonstrate one type of intelligence does not guarantee comparable aptitude in a different type of intelligence (Gardner, 2006). Gardner identified eight forms of intelligence which he claimed were autonomous and could be drawn on individually or simultaneously to problem-solve, including “linguistic”, “logical-mathematical”, “spatial”, “musical”, “bodily-kinesthetic”, “naturalistic”, “interpersonal” and “intrapersonal” intelligences (Davis et al., 2011, p485). He argued that only two of these intelligences were being valued and tested for in modern state schools; “linguistic” and “logical-mathematical” – the combination of which he labelled “academic intelligence” (Davis et al., 2011). Indeed, the D&T qualification for the British secondary school (GCSE) consists of 50% coursework with a rigorous amount of written work and 50% memory-recall exam, which is 2-hours long (AQA, 2023). I am troubled that practical work is not highly graded in D&T GCSE assessment, while academic intelligences are. It is reasonable to assume that talented students with non-academic, nonverbal biases may internalise a lack of confidence in the D&T classroom due to this.

However, Gardner has been heavily criticised for failing to establish measures for his eight intelligences, and with the onset of neuroscience, subsequent factor studies have shown no evidence for individual neural processes for these (Waterhouse, 2023). Gardner maintained that his research was based on empirical studies, but did concede that neither psychometric tests, neuroimaging techniques, nor exams yet exist to test aptitude in specific intelligences (Davis et al., 2011). Davis notes that although we have no existing set of tests to measure spatial intelligence, for example, we might conclude that someone is an expert in this if they are a successful sculptor or architect (Davis et al., 2011). Since my subjects were all students, I could not assess their careers. Regardless, my research takes inspiration from the ambitions of the eight intelligences as “intelligence profiles”, rather than scientifically falsifiable cognitive measures (Waterhouse, 2023). In search of standardised tests for design abilities, I turned to English educational policy guidelines.

8.2 So how do we test for non-academic intelligences?

Between 2007 and 2010 The Department for Children, Schools and Families (DCSF) released guidelines describing children with “academic abilities” in subjects such as English, science and mathematics as “gifted learners”, and children with “applied skills” in subjects such as art and physical education as “talented learners” (Twissell, 2011). These guidelines dictated that gifted learners should be assessed with tests, and talented learners should be assessed through teacher assessment. Twissell argues that this distinction is too simplistic for D&T which does not fit into either category exclusively (Twissell, 2011). Twissell argues that this disparity extends to a lack of D&T-specific assessment, which formed the rationale for his 2011 study assessing whether the Middle Years Information System (MidYIS) and YELLIS Cognitive ability tests (CATs) were appropriate ways to measure “giftedness” in D&T students (Twissell, 2011). The study concluded that new, D&T-specific methods should be used to identify giftedness in D&T students, rather than the existing cognitive tests in place, and suggested measuring student "use of creativity". Twissell never explained how to test for "use of creativity", but he did concede that using the nonverbal subset tests from the CATs exams would be a valid compromise since they draw upon visual-spatial ability (Twissell, 2011). Armed with this information, I approached the SEND hub of my placement school, which presented me with the RPM, a nonverbal test for problem-solving and the processing of visual information (Frost et al, 2018). This widely used nonverbal measure seemed to adhere to the recommendations of both Twissell and Gardner, transcending literacy and academia, accessible to students with English as an additional language (EAL) and to some students with special educational needs and disabilities (SEND) (Frost & Ottem, 2018, p. 265). RPMs focus on a subset of nonverbal intelligence named "eductive" ability (Raven et al., 1994, p. 22), which I will explore below.

8.3 Confidence.

Confidence is described by several psychological constructs, with two of the most prominent being related but distinct; self-efficacy and self-concept (Bong & Clark, 1999). Bandura defined self-efficacy as the confidence one has in their ability to execute certain behaviours to achieve specific outcomes (Bandura et al., 1999). Fouad and Smith created a self-efficacy scale for middle-school students (Fouad et al., 1997), which was adapted further by Panorama Education to create a survey intended to gauge subject-specific self-efficacy (Panorama Education, 2023). I adapted these to compare confidence across twelve core subjects (figure 1).

However, the interests of this paper do not lie solely with students' confidence in their D&T ability, but also with their perception of the value of that ability. To address this, self-concept is useful in discussing the self-perception of students in more general terms (Bong & Clark, 1999). Frost and Ottem (2018) found that "academic self-concept" depends on performance in verbal, nonverbal, and reading skills (p. 265). Given the crucial role of verbal and literacy skills in assessing all subjects, individuals with a nonverbal bias might develop a negative academic self-concept, including in D&T, even if they excel in nonverbal tasks that are essential for design-related abilities. For this reason, I adapted the second survey (figure 2) to compare perceptions of how intelligent a student needs to be to do well in each core subject. By doing this I hoped to gauge whether students with high levels of self-efficacy in D&T might also show low levels of self-concept by ranking D&T as requiring little intelligence.

8.4 Leaderboard and trophies.

During my teaching placements, I observed highly effective behaviourist-inspired extrinsic reward systems (Karpov, 2014) such as public charts with gold stars, "student of the lesson" affirmations or class-quiz league tables. Inspired by these, I created a leaderboard for the RPMs to instil a sense of pride and kept plastic trophies on display for the winners. The ceremony of revealing results each class catalysed excitement and prestige associated with "eductive intelligence". However, Kohn discusses the pitfalls of extrinsic motivators and explores how they might undermine intrinsic motivation and creativity (Kohn, 1999). In my research I found the leaderboard to inspire confidence, however, it seemed to overpower the verbal persuasion I was using in class, ultimately leading to the RPMs subjugating any other form of intelligence praised, as I will discuss below.

Figure 14.
Survey A, taken in lesson 1 and lesson 9, before and after the intervention.

How confident are you that you can do the hardest work that is assigned in your subjects?

Art & Design	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Design & Technology	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
English	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Geography	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
History	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
ICT & Computer Science	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Mathematics	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Music	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Modern Foreign Languages	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Physical Education	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Religious Education	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Science	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident

Name: .... Class: ....

Figure 2.
Survey B, taken in lesson 1 and lesson 9, before and after the intervention.

How intelligent do you need to be to do well in these core subjects?

Art & Design	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Design & Technology	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
English	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Geography	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
History	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
ICT & Computer Science	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Mathematics	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Music	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Modern Foreign Languages	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Physical Education	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Religious Education	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent
Science	Not at all intelligent	Slightly intelligent	Somewhat intelligent	Quite intelligent	Extremely intelligent

Name: .... Class: ....

8.5 Culture wars.

Following my literature review, I realised that my concerns about D&T extended further than I initially thought. Given the impact of cultural context on confidence (Bandura et al., 1999), and the education sector's bias towards academic intelligence (Gardner, 2006), I was persuaded that England needs a significant cultural shift to address this (Fouad et al., 1997). This was beyond my study's scope, so I focused on my Year 8 D&T class, celebrating various intelligences not typically recognised in English state schools. I will now discuss how I attempted this.

9. METHODOLOGY

9.1 Sample and Action Research.

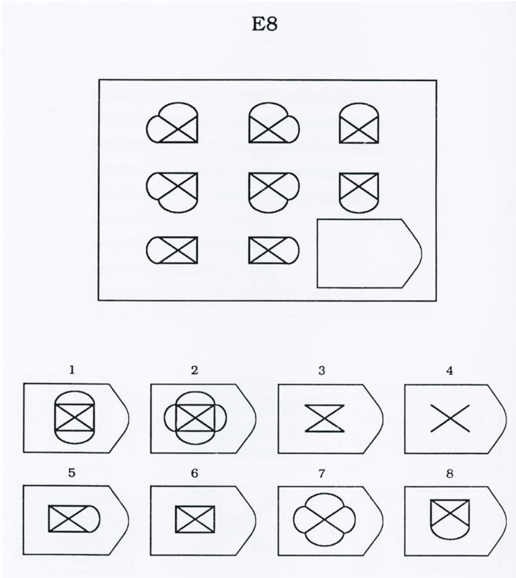
The intervention was conducted with 21 Year 8 students in a mixed-ability D&T class at a rural Norfolk secondary school, with 11 male and 10 female students. 2 were ethnically Black, 17 White British and 2 White European, with 2 EAL, 9 SEND, and 6 Pupil Premium students. To actively address issues and improve teaching, I utilised action research (Cohen et al., 2011), yielding both quantitative and qualitative data through surveys, tests, bookwork, interviews, and triangulating findings with previous grades and discussions with previous D&T teachers. Only the most relevant data gathered is presented in this paper. Since my sample was limited to one year-eight class of 21 students, the results from my research are not generally applicable but rather serve as a case study from which further inquiry could arise.

9.2 RPM and Surveys.

RPM tests (figure 3) were conducted in silence in the first 10 minutes of each class throughout the six-week SoW (table 9). They were completed in books, marked after each class, and scores averaged with 3 to 7 frontrunners entering a public-facing leaderboard. This was revealed at the beginning of the next class, before eliciting answers from the frontrunners. The data was logged and analysed lesson-by-lesson, with triangulation of data allowing for comprehensive analysis of who presented design-specific intelligences, alongside demographic differentiations (Cohen et al., 2011).

Quantitative data was logged from Surveys A and B (figures 1 and 2, tables 1-8) in the first and last classes of the intervention. Following the intervention, I conducted semi-structured interviews with the leaderboard students to gain rich qualitative data about their perceptions of D&T, their confidence, intelligence, and whether the leaderboard had changed these.

Figure 3.
Example question from the RPM test from set E, testing "eductive" nonverbal ability.



9.3 SoW.

The SoW, "Designing Our Tomorrow" (DOT), developed by Nicholl and Hosking (2009), required students to empathise with arthritic, visual impairment sufferers and design for their needs, employing a range of intelligences Gardner would call "interpersonal", "spatial", "bodily-kinesthetic" and others. I adapted this SoW, significantly reducing the amount of literacy required to excel. I made use of Gardner's MIs, identifying and praising students who exhibited them, and included student examples in presentations to enhance learning from peers, consistent with self-efficacy boosting methodology mentioned by Fouad and Smith (1997, p.21).

10. RESULTS

10.1 Perceptions of confidence and intelligence.

As tables 1-4 show, my intervention led to an average increase in respect for D&T, rising from 3.1 to 3.3, but self-efficacy in D&T decreased from 3.33 to 3.15. However, in tables 5-8 we can see that students on the final leaderboard showed respect for D&T rising significantly more, from 3, to 3.71, and their confidence rose from 3.71 to 4.

Table 1.
Table showing whole class averaged student indications of "HOW CONFIDENT ARE YOU THAT YOU CAN DO THE HARDEST WORK THAT IS ASSIGNED IN YOUR SUBJECTS?" in lesson 1 (Survey A).

Subject	Average self-efficacy in the subject - lesson 1
1) P.E.	3.57
2) English	3.43
3) Science	3.38
4) DT	3.33
5) Mathematics	3.29
6) History	3.24
7) ICT	3.19
8) Geography	2.86
9) Art and Design	2.81
10) Music	2.76
11) R.E.	2.67
12) MFL	2.52

Table 2.
Table showing whole class averaged student indications of "HOW CONFIDENT ARE YOU THAT YOU CAN DO THE HARDEST WORK THAT IS ASSIGNED IN YOUR SUBJECTS?" in lesson 9 (Survey A).

Subject	Average self-efficacy in the subject - lesson 9
1) P.E.	3.55
2) History	3.5
3) Science	3.4
4) English	3.3
5) Mathematics	3.25
6) DT	3.15
7) Music	3.1
8) ICT	3
9) Art and Design	2.95
10) Geography	2.8
11) R.E.	2.75
12) MFL	2.65

Table 3.
Table showing whole class averaged student indications of "HOW INTELLIGENT DO YOU NEED TO BE TO DO WELL IN THESE CORE SUBJECTS?" in lesson 1 (Survey B).

Subject	Average intelligence needed for the subject - lesson 1
1) Science	4.33
2) Mathematics	4.29
3) English	3.86
4) ICT	3.57
5) History	3.29
6/7) Art / Geography	3.19
8) MFL	3.14
9) DT	3.1
10) Music	2.9
11) P.E.	2.71
12) R.E.	2.48

Table 4.
Table showing whole class averaged student indications of "HOW INTELLIGENT DO YOU NEED TO BE TO DO WELL IN THESE CORE SUBJECTS?" in lesson 9 (Survey B).

Subject	Average intelligence needed for the subject - lesson 9
1) Science	4.19
2) English	3.76
3) Mathematics	3.71
4) ICT	3.52
5) DT	3.33
6) History	3.31
7) P.E.	3.24
8) Art & Design	3.14
9) MFL	3.05
10) Music	3
11) Geography	2.95
12) R.E.	2.73

Table 5.
Table showing averaged final leaderboard students' indications of "HOW CONFIDENT ARE YOU THAT YOU CAN DO THE HARDEST WORK THAT IS ASSIGNED IN YOUR SUBJECTS?" in lesson 1 (Survey A).

Subject	Average self-efficacy in the subject - lesson 1
1) P.E.	3.86
2,3,4) DT / ICT / Music	3.71
5) History	3.57
6) Art and Design	3.43
7) English	3.29
8) Maths	3.14
9) Science	3
10,11) R.E. / MFL	2.86
12) Geography	2.57

Table 6.
Table showing averaged final leaderboard students' indications of "HOW CONFIDENT ARE YOU THAT YOU CAN DO THE HARDEST WORK THAT IS ASSIGNED IN YOUR SUBJECTS?" in lesson 9 (Survey A).

Subject	Average self-efficacy in the subject - lesson 9
1) History	4.14
2,3,4) Art / DT / Music	4
5,6) P.E. / ICT	3.71
7) Science	3.43
8,9,10) English / Maths / R.E.	3.29
11,12) MFL / Geography	2.43

Table 7.
Table showing averaged final leaderboard students' indications of "HOW INTELLIGENT DO YOU NEED TO BE TO DO WELL IN THESE CORE SUBJECTS?" in lesson 1 (Survey B).

Subject	Average intelligence needed for the subject - lesson 1
1) Mathematics	4.14
2,3) ICT / Science	4
4) Music	3.71
5) English	3.57
6) Art and Design	3.43
7) History	3.29
8,9,10) DT / Geography / MFL	3
11) P.E.	2.86
12) R.E.	2.29

Table 8.
Table showing averaged final leaderboard students' indications of "HOW INTELLIGENT DO YOU NEED TO BE TO DO WELL IN THESE CORE SUBJECTS?" in lesson 9 (Survey B).

Subject	Average intelligence needed for the subject - lesson 9
1,2) Science / ICT	4.14
3) English	4
4) Mathematics	3.86
5,6,7) DT / History / MFL	3.71
8,9) Art and Design / Music	3.57
10) R.E.	3.14
11) P.E.	3
12) Geography	2.57

10.2 RPM.

Table 9.
Table showing the scores per Set of Raven Progressive Matrices (RPM). The students who entered the leaderboard are highlighted in yellow, with the students on the final leaderboard in green. There were 7 leaderboards in total, with no leaderboard in lesson 1 since frontrunners were not yet apparent.

Student	Set A	Set B	Set C	Set D	Set E	Total	Average	Nonverbal Y7 CAT scores
Student 1	12	7	8	0	7	34	6.80	101
Student 2	6	6	3	8	0	23	4.60	74
Student 3	12	12	9	10	6	49	9.80	95
Student 4	12	12	11	10	7	**52**	10.40	103
Student 5	12	12	11	11	8	**54**	10.80	109
Student 6	11	0	5	0	0	16	3.20	110
Student 7	11	10	8	6	2	37	7.40	-
Student 8	12	11	8	1	5	37	7.40	77
Student 9	12	12	11	11	8	**54**	10.80	95
Student 10	12	12	9	8	6	47	9.40	102
Student 11	12	11	10	9	7	49	9.80	104
Student 12	11	10	12	11	8	**52**	10.40	114
Student 13	0	11	10	9	7	37	7.40	107
Student 14	12	11	9	8	2	42	8.40	84
Student 15	12	12	9	10	7	**50**	10.00	98
Student 16	12	11	10	9	7	49	9.80	122
Student 17	12	12	4	11	8	47	9.40	103
Student 18	11	12	11	9	7	**50**	10.00	114
Student 19	12	12	9	9	9	**51**	10.20	104
Student 20	1	12	11	11	9	44	8.80	108
Student 21	12	11	6	9	6	44	8.80	103

10.3 SEND students.

5 of 9 SEND students were on the final leaderboard. On average, these students' perceptions of D&T intelligence shifted from 3 to 3.8, with their confidence rising from 3.8 to 4. On average, their confidence across all subjects rose from 3.45 to 3.67, with the largest shifts in art, +0.8, history and R.E., +0.6, and seeing a drop in confidence in both language-based subjects, English and MFL, -0.4.

10.4 Interviews.

Following the intervention, I interviewed 8 students who had entered the leaderboards. This was in pairs. They unanimously discussed disbelief at their achievement, with statements such as "If I'm completely honest, I was just like 'maybe it was just like all the guesses I got correct'", and "I'm shocked! [...] I hoped I'd be, but I didn't think I would be." Two students initially thought it was a mistake in my marking. Three discussed how some of their classmates were better in maths and science classes, so they assumed those students would do better across all classes, and discussed their lack of confidence due to a lack of academic ability, working memory, and literacy skills.

All these students appeared to sit a little taller and further forward, holding their trophies and eager to discuss their experiences. They identified very positively with entering the leaderboard, expressing confidence in themselves and each other with statements such as; "We're very proud", and "excited", and "Oh, my God, I actually know this stuff", and "I was so proud of you when I saw you joined us on the leaderboard".

The two highest-scoring students in the RPMs, Students 5 and 9, discussed enjoying this D&T unit because there was no physical making. They explained that neither of them had finished making their product in the previous D&T rotation and had little ability in manufacturing. CAT scores indicated "mild verbal biases" for both, predicting lower attainment in D&T.

11. DISCUSSION

The results suggest this intervention raised the status of D&T in my class and boosted the confidence of students on the leaderboard. However, I believe basing the leaderboards solely on RPM was a limitation, as it failed to celebrate other design abilities and perpetuated the idea that the students with the best RPM scores were the best designers. The top two students on the leaderboard self-indicated low manufacturing abilities in the interview, and Raven conceded that there are many kinds of meaning-making activities which the RPM cannot highlight (Raven et al., 1994). By triangulating the RPM results with CAT scores and bookwork, I have concluded that the RPM was not the correct metric with which to form the leaderboard.

Student 16, for example, never entered the leaderboard, but had the highest nonverbal CAT scores in the class and demonstrated excellent bookwork (table 9). Their teacher-assessed work demonstrated more complex problem-solving and draughtsmanship than leaderboard students such as 3, 10, 17, 18 or 19. The survey results suggest that this damaged student 16's confidence.

It is a similar situation for students 20 and 21, making this a key theoretical and ethical failing of my intervention, consistent with Kohn's discussions of extrinsic motivators as potentially demotivating (Kohn, 1999). However, the leaderboard did significantly boost whole-class engagement, and the confidence of those entering it, and I would assert that the top five in the RPM leaderboards were among the top six students in the D&T class, based on bookwork.

Six of the nine students who entered the leaderboard were SEND students. When interviewed, they unanimously discussed disbelief at entering the leaderboards, describing a lack of academic ability and working memory, demonstrating the severity of bias for verbal/academic assessment and for the impact on their self-concept. Much like Spearman's "g" measure of intelligence (Davis et al., 2011), they expected students who excelled in verbal/academic subjects to excel in the RPM tests too. I posit that this betrays a cultural bias towards verbally intelligent students, with sinister ramifications for what we label as SEND.

12. CONCLUSION

At the heart of this paper was a belief that the English education system enacts systemic discrimination against nonverbally intelligent students by teaching and assessing non-academic subjects via academic means. My aim was to disrupt this culture by celebrating non-academic intelligences in non-academic classes. The leaderboard was a powerful tool, and the shift I logged in SEND student attainment and confidence supported my expectations. However, my reductive focus on testing for "eductive" intelligence failed to celebrate many other forms of intelligence needed to create high-level design and possibly damaged the confidence of students with potential. For these reasons, I would continue to use the leaderboard, but with a far greater focus on teacher-assessed bookwork. Nationally, I would urge for a change in the way we assess D&T; dropping memory-based exams entirely, lessening the emphasis on literacy, and dramatically boosting the assessment of intelligences used in design industries such as problem-solving, draughtsmanship, and the ability to conceptually and physically manipulate in three-dimensional space.

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Developing the Professional Knowledge of Technology Student Teachers via a Parallel Approach: A Longitudinal Study

Rina Grobler, University of Johannesburg, South Africa, rinag@uj.ac.za
Piet Ankiewicz, University of Johannesburg, South Africa, pieta@uj.ac.za

ABSTRACT

In a small scale, four-year longitudinal, quasi-experimental research project, technology student teachers could study the school subject in parallel, together with the development of discipline knowledge (or their major) within the broader development of their pedagogical content knowledge (PCK). We investigated the performance of students – who had studied the school subject at school and those who studied it in a postschool-university context – in their (1) major, (2) specialised methodology/ pedagogy and (3) their experiences and competencies during their final year work-integrated learning period in schools. We interpreted the findings within the broader theoretical framework of Shulman's PCK by relating the first aspect to content knowledge, and the second aspect to pedagogical knowledge. We found that the parallel approach to PCK development in technology teacher education seems to be viable to increase the number of prospective technology student teachers, with the requirement that it happens within a social constructivist, co-operative learning environment with ample opportunities for cognitive and practical apprenticeship in a community of practice. However, by building on Shulman's PCK and Gardner's cognitive theory, Banks has developed the internationally acknowledged model of teacher professional knowledge (TPK). It entails the active interaction between subject knowledge, school knowledge, pedagogical knowledge and experience which underpins the personal subject construct of the teacher. The purpose of this conceptual paper is to reinterpret the previous findings through the lens of Banks' TPK model by following a qualitative meta-synthesis as research methodology. In conclusion, implications for curriculum design of initial professional education of technology teachers are drawn.

Keywords: Technology education, Technology teacher education, Pedagogical content knowledge (PCK), Teacher professional knowledge (TPK)

1. INTRODUCTION

Universities in South Africa and in various other countries play an important role in the education of technology teachers (Ankiewicz, 2021). Despite technology subjects being labelled as priority subjects in South African schools, extremely low numbers of students have enrolled for these subjects over the past few years, and also at the university where the research was conducted (Ankiewicz, 2018; Grobler, 2018). To combat the trend of decreasing enrolment numbers for the four-year BEd degree in technology education, students who did not study the school subject Engineering Graphics and Design (EGD) at school could study it at university in parallel with their major, Engineering Graphics and Technology Education (EGTE). This is a novel idea as it is usually assumed that students' majors are built on qualifications gained earlier in their education. During the first three years of study, some of the students had to take the school subject EGD and the majors (subject knowledge) simultaneously to develop their pedagogical content knowledge (PCK). The school subject also served as a base for their parallel PCK development (Grobler & Ankiewicz, 2022a). To better accommodate students who did not have EGD in Year 12, the pedagogical practices were reconsidered to provide more intensive support to these students (Grobler & Ankiewicz, 2022a). This was done, inter alia, by assigning a double period per week during their first and second year of study for practical apprenticeship for Year 10–12 EGD (Grobler & Ankiewicz, 2022b). This was facilitated by an expert, who was a schoolteacher, and who was appointed as a tutor and provided guidance in a peer-based collaborative learning environment (Jakovljevic & Ankiewicz, 2016). During their second year of study, an additional expert was appointed as a tutor assistant to provide individual attention during tutorials and consultation times to assist the students to cope better with the school subject (Grobler & Ankiewicz, 2022b). At the end of the second year the assistance of the tutorials, tutor and tutor assistant was terminated and from there on the students had to take full responsibility for their own learning.

The findings of this longitudinal study were reported at different stages of its development during the past five years (Grobler, 2018, 2019; Grobler & Ankiewicz, 2021, 2022a, 2022b). A comprehensive report on (*The) the viability of diverting from a linear to a parallel approach to the development of PCK in technology teacher education* was compiled by Grobler and Ankiewicz (2022a). The findings were interpreted within the broader theoretical framework of Shulman's (1986, 1987) PCK by relating students' performances in their major to content knowledge, and their experiences and competencies during their Work Integrated Learning (WIL) to pedagogical knowledge. We found that the parallel approach to PCK development in technology teacher education seems to be viable to increase the number of prospective technology student teachers, because more students get the possibility of enrolling even though they did not study EGD in Year 12. The requirement is that it happens within a social constructivist, co-operative learning environment with ample opportunities for cognitive and practical apprenticeship in a community of practice. However, by building on Shulman's (1986, 1987) PCK and Gardner's (1983) cognitive theory, Banks (1996) developed the internationally acknowledged model of teacher professional knowledge (TPK). This model entails the active interaction between subject knowledge, school knowledge, pedagogical knowledge and experience which underpins the personal subject construct of the teacher. It seems that Banks' TPK model holds affordances for our previous study. The purpose of this conceptional paper is to reinterpret the previous findings of our study through the lens of Banks' TPK model through a qualitative meta-synthesis as research methodology.

14. BANKS' MODEL FOR CONCEPTUALISING TEACHER PROFESSIONAL KNOWLEDGE

14.1 Foundations of Banks' model for teacher professional knowledge

Banks et al. (2004), as part of the 'DEPTH' study, presented a graphic framework (Figure 1) that helped to visualise the dynamic relationship between the types of knowledge implied by the diagram. This framework is not a Venn diagram, but it illustrates the three overlapping spheres which represent school knowledge, subject knowledge, and pedagogical knowledge respectively and a rectangle over the overlapping areas of the spheres form the teacher's personal subject construct or professional knowledge (Banks, 2022). Therefore, a teacher's personal subject construct comprises a combination of school knowledge, subject knowledge and pedagogical knowledge supporting each other. Furthermore, Banks et al. (2004) stated that a teacher's subject knowledge is enhanced by his or her own pedagogy in practice and by the contextual expectations which form part of their school knowledge, thus a teacher often understands a topic better after teaching it to students (Engelbrecht & Ankiewicz, 2016). For example, a teacher's subject knowledge is transformed by their own pedagogy in practice and by the resources which form part of their school knowledge. The active interaction of subject knowledge, school knowledge and pedagogical knowledge brings teacher professional knowledge into being (Banks, 2022; Banks & Barlex, 2014; Banks et al., 2004).

Banks et al. (2005) were critical of Shulman's work (1986) which is based on a teacher-centred pedagogy which focuses primarily on the pre-existing skills and knowledge that the teacher possesses, rather than on the process of learning. Gardner (1983) provides a perspective on professional knowledge which is rooted in a fundamental reconceptualization of knowledge and intelligence. Gardner's (1983) theory of multiple intelligences encourages a perspective on pedagogy that emphasises student understanding or the so-called learner perspective. Therefore, the focus shifts from teachers' knowledge to learners' understanding, from classroom technique to purpose (Banks et al., 2005).

Shulman (1987) identified seven types of teacher knowledge which Williams et al. (2016) described as domains or categories dealing with the complexity of the knowledge base that experienced teachers draw upon. MacNamara (1991) identified the following types of teacher knowledge: subject content knowledge; pedagogical knowledge; and school-subject knowledge. These types of knowledge were adapted and expanded by Banks (2008) as follows:

14.2 Subject knowledge

If the aim of teaching is to enhance children's understanding, then teachers themselves must have a flexible and sophisticated understanding of subject knowledge in order to achieve this purpose in the classroom. Therefore, teachers' subject knowledge influences the way in which they teach, and teachers who know more about the subject will be more interesting and adventurous in their methods and, consequently, more effective (Banks & Barlex, 2014). Furthermore, teachers with only a limited knowledge of a subject may avoid teaching difficult or complex aspects of it and teach in a manner which avoids learner participation and questioning which fails to draw upon learner's experience (Banks, 2008).

14.3 Pedagogical knowledge

In contrast to Shulman's (1986) pedagogical content knowledge, Gardner's (1983) work is rooted in a fundamental reconceptualization of knowledge and intelligence. Due to his theory of multiple intelligences pedagogy can now be viewed from a perspective on student understanding. There is now an emphasis on the *process* of pedagogy and therefore, a wider term of '*pedagogical knowledge'* considered a more appropriate term for use (Banks, 2008).

14.4 School knowledge

Banks (2008) added 'school knowledge' as another type of teacher knowledge which is not knowledge of the school context, but rather the transposition of subject knowledge. For example, by altering technology to make it accessible to the school students, a distinctive type of knowledge, 'school technology', is formulated. 'School technology' is a function of the schooling process and would exist even without a prescribed curriculum to guide its formulation and so is a general term applicable across different country contexts. Therefore, school knowledge is greatly informed by the local school ethos, common practices and authenticity of activities that students are required to undertake during their work in technology lessons (Banks, 2008). Technology student teachers must understand that the emphasis is on the design 'process' and 'portfolio' and their importance in the assessment process. The relationship between subject and school knowledge can be explained by Newton's second law as an example. From Newton's Principia the second law reads: *The rate of change of momentum of a body is proportional to the resultant force acting on the body and is in the direction of that force*. In symbolic form this becomes $\mathbf{F} = d\mathbf{p}/dt$. However, in school knowledge which deals with a single particle of constant mass, this formulation transposes (and is equivalent) to $\mathbf{F} = m\mathbf{a}$, because $\mathbf{F} = d\mathbf{p}/dt = d/dt\ (m\mathbf{v}) = m\ d\mathbf{v}/dt = m\mathbf{a}$.

14.5 Personal subject construct

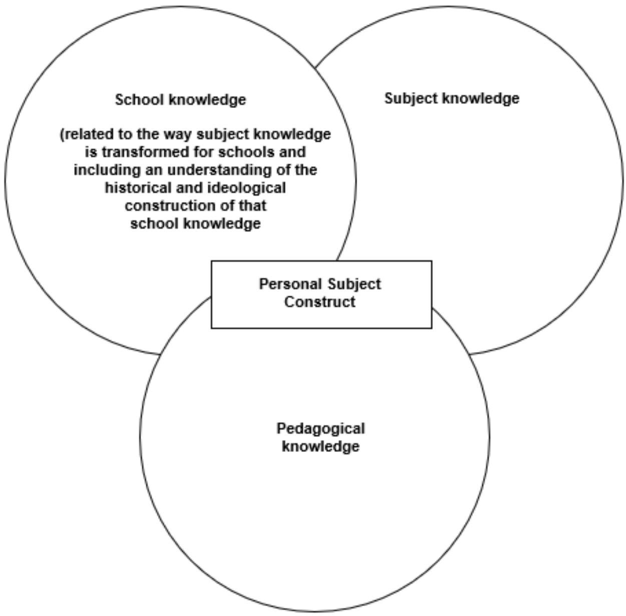
A teacher's professional knowledge is underpinned by his/her past experiences of learning technology, the personal view of what constitutes 'good' teaching and a belief in the purpose of technology as a school subject (Banks & Barlex, 2014). Therefore, the personal subject construct is a combination of school knowledge, subject knowledge and pedagogical knowledge which blend with other influences to provide a view of purpose, value content and methods of design and technology as a school subject (Banks, 2022). Furthermore, a student teacher must question his or her personal beliefs about their subject as they work out a rationale for their behaviour in the classroom. Banks (2008) believes that a teacher's 'personal subject construct' will have an important impact on the way in which they respond to a professional development activity.

14.6 Banks' revised model for teacher professional knowledge

Banks (2022) proposed Figure 1 as a revised version of previous models and provides a new starting point for conceptualising teacher professional knowledge. Shulman's category of subject content knowledge is retained but represented as subject knowledge. School knowledge, which includes Shulman's (1987) curriculum knowledge, is viewed as the transposition of subject knowledge and not merely a knowledge of the school context. Curriculum knowledge is

"…knowledge of relevant mandated curricula" (Banks, 2022:83), "…with particular grasp of the materials and programs that serve as 'tools of the trade' for the teachers" (Shulman, 1987:8). Pedagogical knowledge is more than the generic set of beliefs and practices that inform teaching and learning, it must be integrated into an understanding of the important relationship between subject knowledge and school knowledge. According to Banks (2022) a teacher's subject knowledge is transformed by their own pedagogy in practice and by the resources which form part of their school knowledge. The active interaction of subject knowledge, school knowledge and pedagogical knowledge leads to the personal subject construct of the teacher (Banks & Barlex, 2014). This construct includes past knowledge, experiences of learning, a personal view of what constitutes 'good' teaching and belief in the purposes of the subject.

Figure 1.
Teachers' professional knowledge (Banks, 2022:62)



The context that underpinned our study will be discussed briefly.

15. CONTEXT OF THE STUDY

Within the afore-mentioned collaborative learning environment and apprenticeship, the students who enrolled for this four-year programme either studied EGD in Year 12 at school and will be referred to as 'Group Y', or studied EGD postschool as part of an apprenticeship at university and will be referred to as 'Group Z'. The number of students and a breakdown in terms of cohorts and gender for both groups are given in Table 1. During their final year only one Group Y student and four Group Z students remained in the programme.

It is unusual to teach school knowledge in a university context. However, during the apprenticeship we simulated the school context, inter alia, by letting an expert, who was a schoolteacher, teach the Group Z students. We argue that the apprenticeship, which focused on the school subject EGD, exposed the student teachers to school knowledge, as the result of transposed subject knowledge, in a postschool-university context. However, it did not intend to develop the student teachers' competence to transpose subject knowledge into school knowledge, which they were supposed to acquire in the specialised methodology modules at the university and WIL in schools. During the specialised methodology/pedagogy modules, the students studied, inter alia, various teaching/pedagogical approaches, strategies, and methods which are required for the transposition of their subject knowledge to school knowledge, and which they then applied during WIL.

The students studied subject knowledge in their major (EGTE 1, 2 and 3) and generic pedagogy (Teaching Studies 1, 2, 3 and 4 and Teaching Methodology and Practicum 2). During their third year they also studied the transposition of subject knowledge into school knowledge, as well as pedagogical knowledge in the specialised methodology/pedagogy module (Teaching Methodology and Practicum for Senior Phase [Year 7–9] and Further Education and Training Phase [Year 10–12]), which focused on both technology and EGD. During their fourth year they practically applied the theoretical knowledge on the transposition of subject knowledge into school knowledge, as well as pedagogical knowledge in the module Teaching Methodology and Practicum for Further Education and Training Phase EGD. It also included ten weeks of WIL in approved schools – three consecutive weeks during the first semester and seven consecutive weeks during the second semester (Grobler & Ankiewicz, 2022b). Table 1 summarises the contextual information regarding the study.

The discussion shifts now to a reinterpretation of the previous findings through the lens of Banks' TPK model by means of a qualitative meta-synthesis.

Table 1.
Summary of the contextual information regarding the study.

Type of knowledge	Year, cohorts and module	Group Y	Group Z
School knowledge (Engineering graphics and design [EGD] as the result of transposed subject knowledge in Year 12)		Studied EGD in school context (up to Year 12)	Studied EGD in a postschool-university context
Subject knowledge (number of cohorts and students)	Year 1, EGTE 1, 2 cohorts [22 (12 male; 10 female)]	8 (6 male; 2 female)	14 (6 male; 8 female)
	Year 2, EGTE 2, 2 cohorts [21 (12 male; 9 female)]	8 (6 male; 2 female)	13 (6 male; 7 female)

	Year 3, EGTE 3, 1 cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)
Transposing subject knowledge into school knowledge (including pedagogical knowledge)	Year 3, TMP: SP & FET, I cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)
Pedagogical knowledge (including transposing subject knowledge into school knowledge)	Year 4, TMP: FET EGD, I cohort [7 (3 male; 4 female)]	2 (1 male; 1 female)	5 (2 male; 3 female)
	Year 4, WIL, 1 cohort [5 (2 male; 3 female)]	1 (0 male; 1 female)	4 (2 male; 2 female)

16. REINTERPRETING THE FINDINGS OF THIS LONGITUDINAL STUDY THROUGH THE LENS OF BANKS' TPK MODEL

16.1 Developing students' subject knowledge

For both cohorts in the first year, Group Y performed statistically significantly higher in EGTE 1 than Group Z students for both cohorts. By the end of the second year for Cohort 1, the performance of Group Y and Group Z was similar in EGTE 2. However, for Cohort 2 the performance of Group Y was statistically higher than those of Group Z in EGTE 2, which illustrates that findings can be very specific for a particular cohort (Grobler & Ankiewicz, 2022a). Furthermore, for Cohort 1 the performance of Group Y students (69%) and Group Z students (68%) in EGTE 3 was practically similar. Unfortunately, due to the small number of continuing students in the third and fourth year it was pointless to determine the statistical significance of any differences in performance between Group Y and Z. Thus, provided that ample support is available to meet students' needs and challenges they experience, Group Z students can succeed in developing their subject knowledge and skills at university level, which is a crucial part of the knowledge base for teaching (Rohaan et al., 2009).

Looking through the lens of Banks, this would indicate that Group Z students can successfully develop their subject knowledge, although it might imply a higher workload and additional time to catch up with Group Y students. Extra support should be provided during the first two years of their study to assist the Group Z students to scaffold the development of their subject knowledge. The comparisons between the two groups are based on *de facto* descriptions of their performance without drawing any causalities therefrom.

16.2 Transposing subject knowledge into school knowledge (including pedagogical knowledge)

According to Banks (2022) 'school knowledge' does not mean a knowledge of the school context but rather the transposition of the subject knowledge to make it accessible to learners, whereby a distinctive type of knowledge is formulated, for example 'school technology' (Banks & Barlex, 2014). The focus at university level should rather be on teaching students how to transpose subject knowledge into school knowledge by developing their competence to interpret the curriculum, draw up lesson plans, design assessment tasks, and learn about the compulsory formal assessment for promotion. When we assert that Group Z lacked school knowledge, we mean that they had not experienced school knowledge as the result of transposed subject knowledge by teachers. However, both groups at the start of their fourth year lacked the competence to transpose subject knowledge to school knowledge for school students. The performance of both groups in their specialised methodologies was practically similar. During the third year Group Y achieved 60% and Group Z 63%, and during the fourth year Group Y achieved 75% and Group Z 77%. During the focus group interview after WIL a Group Z student recognised the difference between subject knowledge and school knowledge by saying that "EGD at school is different…−…the knowledge I have acquired at university is not classroom knowledge". Although the student teachers studied to interpret and teach the prescribed, national school curriculum (CAPS) the Group Z students missed out on the valuable past experiences of studying EGD at school and through Lortie's (1975) 'apprenticeship of observation' observing teachers transposing subject knowledge into school knowledge practically. During the individual interview after WIL the Group Y student acknowledged that the lecturers and the tutor helped her to improve her school knowledge and to prepare her well for WIL.

16.3 Developing students' pedagogical knowledge (including transposing subject knowledge into school knowledge)

To measure these students' PCK during their WIL experience in their final year of study, we relied on Content Representations (CoRes) and Pedagogical and Professional experience Repertoires (PaP-eRs) (Loughran et al., 2004). For lesson planning, as part of the CoRes, students applied their school knowledge by identifying 'big ideas' of the particular content or topics prescribed by the CAPS and set out by the annual teaching plan for the specific time period coinciding with their WIL. The big ideas for a specific topic highlight several concepts as being commonly viewed as important for students to learn in order to understand this topic (Loughran et al., 2004). By relying on both their subject and school knowledge, the students also implemented the set of eight pedagogical questions/prompts which interrogate each big idea (De Miranda, 2018; Loughran et al., 2004; Williams et al., 2016) across the various lesson phases.

The lesson presentation assessment rubric incorporates the various phases of the lesson such as the lesson design (written planning), introduction, presentation style, PCK, resources, classroom management and professionalism, assessment, conclusion and the student's reflection on the lesson plan and presentation. PaP-eRs were developed from students' detailed descriptions/reflections and as a result of discussions about situations/ideas/issues pertaining to the CoRes, as well as classroom observations (Loughran et al., 2004). The findings from the lesson presentation assessment during WIL indicated that the PCK of the Group Y student was slightly higher than the mean score of Group Z (82% compared to 78%). Therefore, according to Grobler and Ankiewicz (2021), the performance of students during these lesson presentations was regarded as competent as they demonstrated the required pedagogical knowledge (Banks et al., 2004; Shulman, 1986, 1987).

The students' PCK was also ascertained by using a classroom observation schedule consisting of 15 aspects based on CoRes and most of the aspects covered by the afore-mentioned rubric, including the observation of students' PaP-eRs. The assessment criteria for each aspect were: not achieved/not competent (1); developing/approaching competence (2); accomplished/competent (3); and exemplary/excellent (4). The scores for Group Z students varied between 1.6 and 2.8 with an average of 2.4 out of a maximum of 4.0 which is an indication of ranging between 'approaching competence' and 'competent' while the Group Y student scored 3.1 which is just beyond 'competent' (Grobler & Ankiewicz, 2021).

The focus-group interview after WIL regarding the experiences of Group Z students during their WIL period revealed that their experiences were good, although challenging. Some of the students felt that they were not well equipped to teach EGD (Grobler & Ankiewicz, 2021). One student mentioned that it was difficult to explain different concepts of EGD to the learners because they did not study the subject at school. The Group Z students felt that they lacked a proper foundation in the subject, and according to Gill (2019), this might compromise their ability to adapt subject matter for the purpose of teaching. However, it was found that the real challenge was when they had to do assessment and specifically the marking of assignments and tests (Grobler & Ankiewicz, 2021). It was recommended that students should gain more experience in the marking of assessment papers during the specialised pedagogy courses to develop their school knowledge before they do their WIL experience in their final year. Overall, the support from the mentor teachers was much appreciated to enhance their pedagogical knowledge.

16.4 Developing students' personal subject construct

The combination of the students' school knowledge, subject knowledge and pedagogical knowledge culminated in their personal subject construct. The findings revealed that both Group Y and Group Z students had similar experiences about the support and guidance by the mentor teachers during their WIL period (Grobler & Ankiewicz, 2021). All of them valued the support and guidance by the mentor teachers, and their perception of not being well equipped for the WIL period was mainly due to their lack of ability to handle assessments. The Group Y student reflected as follows:

> "Overall, the past weeks have been vastly beneficial to both my personal and professional growth. I genuinely feel that my experiences at the school, as well as the mentorship I have received, have helped me grow so much. While I feel saddened by the closure of the work-integrated learning experience for the year, I feel equally delighted to have emerged a better teacher from my experiences throughout the year."

Banks and Barlex (2014) stated that a teacher's professional knowledge is underpinned by his/her past experiences of learning technology which may indicate that the final year students might need special guidance to assist them in becoming familiar with the practice of handling assessment tasks. The students still need experience to develop their 'personal subject construct' which will serve as a crucial starting point for any future professional development activity. If the professional development activity unknowingly clashed with what the teacher thought technology was all about, then they would reject that development as 'a complete waste of time' (Banks, 2008). Table 2 provides a summary of the findings of the study.

Table 2.
Summary of the findings.

Type of knowledge	Year and module	Findings
Subject knowledge	Year 1, EGTE 1	For both Cohorts Group Y performed statistically significantly higher than Group Z.
	Year 2, EGTE 2	For Cohort 1 Group Y and Group Z performed similar. For Cohort 2 Group Y performed statistically significantly higher than Group Z.
	Year 3, EGTE 3	The performance of Group Y and Group Z was practically similar.
Transposing subject knowledge into school knowledge (including pedagogical knowledge)	Year 3, TMP: SP & FET	The performance of Group Y and Group Z was practically similar.
	Year 4, TMP: FET EGD	The performance of Group Y and Group Z was practically similar.
Pedagogical knowledge (including transposing subject knowledge into school knowledge)	Year 4, Aspects of WIL	
	Lesson presentation	The PCK of the Group Y student (82%) was slightly higher than the mean score of Group Z students (78%).
	PCK (CoRes and Pap-eRs)	The scores for Group Z students varied between 'approaching competence' and 'competent' while the Group Y student scored just beyond 'competent'.
	Experiences of WIL	Group Z had good experiences although challenging, and they lacked a proper foundation in the school subject. Some of them felt that they were not well equipped to teach EGD. One student mentioned that it was difficult to explain different concepts of EGD. Unfortunately, the Group Y student did not specifically comment on the WIL experience.
Personal subject construct		Both Groups Y and Z students valued the support and guidance by their mentor teachers during WIL, which added to their growth and development as a teacher.

17. CONCLUSION

The reinterpretation of the previous findings of this longitudinal study through the lens of Banks' TPK model (2022) has shed new light, especially on students' personal subject construct, which was largely overlooked in previous reports. It emphasises the importance of student reflections as part of their Pedagogical and Professional experience Repertoires (PaP-ers). It also confirmed that developing school subject knowledge without prior experience of school knowledge, as transposed subject knowledge at school, can successfully contribute to develop students' professional knowledge to the extent that they can be regarded as 'approaching competence' or 'competent'. The requirement for developing student teachers professionally via this parallel approach is that it happens within a social constructivist, co-operative learning environment (Johnson & Thomas, 1992; Reddy et al., 2005) with ample opportunities for cognitive and practical apprenticeship (Jakovljevic & Ankiewicz, 2016) in a community of practice (Banks, 2008; Banks et al., 2004). However, more focus should be placed on assessment when designing the curriculum of the programme for initial professional education of technology teachers. The students need more experience in the marking of assessment papers during the specialised pedagogy courses before they do their WIL experience. When the students are placed in schools for their WIL period, special care should be taken when the mentor teachers are assigned to the students so that they can assist these students to further develop their personal subject construct and therefore their professional knowledge (cf. Banks, 2022).

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How does ‘Matter’ Matter in Engineering Education?

Annica Gullberg, KTH Royal Institute of Technology / Uppsala University, gullbe@kth.se
Kristina Andersson, KTH Royal Institute of Technology / Uppsala University, kriand2@kth.se
Jenny Ivarsson, Uppsala University, jenny.ivarsson@gender.uu.se
Henni Söderberg, KTH Royal Institute of Technology, hennims@kth.se

ABSTRACT

Practical activities are at the core of learning in engineering. Therefore, such activities are included as important parts of education and curricula. Entities, from simple equipment to advanced instruments, require knowledge of when, why and for what they can and should be used. Emotional outcomes from practical activities may be feelings of success and satisfaction, or disappointment and worries. Such feelings may be crucial for a student’s decision to start, or continue, their science/technology studies.

This project explores how practical activities shape learning processes in two different experimental setups within engineering education. The purpose is to examine how students’ and teachers’ emotional embodiment of scientific/technology practices, through entangled intra-actions with each other and matter/material, influence both teaching and learning. Three methods of data collection were employed: observations, micro-interviews, and interviews.

By using Barad’s theory of agential realism (Barad 2007) and Sara Ahmed’s ‘Cultural Politics of Emotion’ (Ahmed 2004/2012) in the analysis, we found that practical lab activities require many different abilities of the students to be able to navigate in the lab rooms crammed with artefacts. Much of the learning that takes place is bodily and non-verbal, where the teacher's instructions are also bodily and intertwined with the students, materials, and emotions. When a practical moment is repeated, the emotions are transformed or even fade away.

In the discussion we argue that the degree of agency has a substantial impact on the emotional outcomes and that students utilise emotions in order to experience agency.

Keywords: Agential realism, Emotions, Practical activities, Engineering Education.

1. INTRODUCTION

Experimental activities are at the core of learning in science and engineering. The practical conduct of experiments is also something that arouses diverse emotions in students that may affect their learning. Their initial encounters with new materials, whether in school or in higher education, can generate emotions such as desire, excitement, expectation ... or worry, fear of exposing clumsiness, destroying expensive equipment etcetera. While there exists considerable research on experimental work in engineering education, only relatively few studies address the impact of hands-on-activities on students' learning, based on what the non-human material does and what differences in emotion it evokes. We aim to explore how experimental practices shape learning processes, beyond human-human interaction, including the importance of emotions that may arise in connection with these activities in university educational programs. The research questions are: how can student-teacher-material-emotions intra-actions be understood, and what context-specific views of practical skills are expressed, and how?

19. LITERATURE REVIEW

19.1 Agential realism and emotional politics

This project is grounded in physicist and science philosopher Karen Barad's onto-epistemology agential realism (Barad 2007) where the agency of matter is central and arises through intra-actions with humans. The intra-active nature of agency implies that it is not aligned with human intentionality or subjectivity and not limited to human action. Instead, agency is a doing or being, something enacted, and not a property or something that someone or something has. Intra-actions are entangled within what Barad (2003) refers to as phenomena. This means that the primary ontological units are not students, teachers and materials separately and individually, but the phenomena produced through their entangled intra-actions. In agential realism, boundaries between objects are not given once and for all, but constantly contested or confirmed in an iterative way.

Since emotions are part of the phenomena, we also lean on Ahmed's theories of emotional politics (Ahmed 2004/2012) which suggests that emotions can be used as economy, because they become attached to material objects that join some people together while separating others (Ahmed 2006).

Combining emotional politics with the intra-active nature of knowledge production we can analyse the role of emotions in practical activities.

19.2 Laboratory exercises in science and technology education

In comparison between physical and virtual laboratories, De Jong et al. (2013) demonstrate that physical laboratories are understood to have merits and shortcomings. Despite the strong belief in educational contexts and policy documents worldwide regarding the positive significance of hands-on activities in science and engineering, some studies show no improvement in conceptual knowledge outcomes compared to using simulations, which can be partly explained by messy data produced in the lab. For example, first-year secondary school students who conducted virtual chemistry experiments outperformed those who performed physical laboratories in terms of conceptual understanding, partially due to cluttered data produced in the physical lab (Pyatt & Sims 2012). Some studies also indicate that tactile information is unnecessary for developing conceptual knowledge or inquiry skills unless it involves younger children who lack sufficient experience with physical activities (Triona & Klahr 2003). Also, many students perceive experimental exercises as unimportant in their learning (Hofstein & Lunetta 2004). However, knowledge about the messiness of laboratory work also has advantages, as it provides insights into the complexity of scientific work and technological methods, such as handling unexpected events and interpreting measurement errors (Bybee 2000). Other advantages of physical laboratories include acquiring practical skills that in themselves constitute a separate area of knowledge. Another often used argument is that the practical activities make the subject fun and interesting (Lombardi et al. 2014). Nevertheless, the role of instruments, learners' engagement with the material or the intra-actions that support the development of scientific practices remained unexplored. Instead, research on laboratory learning of science focused on language and discourse as the role of argumentation (Driver et al. 2000), students' perceptions of the environment (Hofstein et al. 2001) and social discourse to promote learning in cooperative groups (Jobér 2017). However, more recently, science educators have considered how material feminisms can relate to learning (Otrel-Cass & Cowie 2019), for example by considering how the apparatus in a college science classroom supports the 'intra-action' of students and nature (Milne 2019, Milne & Scantlebury 2019, Taylor & Ivinson 2013, Wink 2020).

19.3 Embodied knowledge and emotions

There is some research exploring student-material interactions in preschool (Günther Hanssen 2018) or in a specific subject. Within craft education research there are examples of how student–material relations emerge (Hofverberg 2019). Such relations can create embodied stories that may involve both pleasurable and unpleasurable experiences and emotions, that effect beliefs and behaviours related to gendered expectancies (Sigurdsson 2014). A corresponding (stereotypical) connection between gender and expectations of practical dexterity have been identified within science education, especially in male-dominated subjects like physics and technology (Danielsson et al. 2018, Gonsalves et al. 2016).

Researchers address different aspects of emotions, including emotional climate in the classroom (Bellocchi et al. 2013), and the intersection of feelings with conceptual and epistemological inquiry (Jaber and Hammer 2016). Their results suggest that feelings are situated and practice-linked and develop in interaction with contextual factors. This aligns with Ahmed's description of emotions as cultural practices, shaped by spaces, objects and people and come into being in contact with others (Ahmed 2004/2012), where this *other* can include the non-human. An illustrative example involves postdoctoral scientists struggling to calibrate mass spectrometers (Lorenz-Meyer 2014). To succeed requires training but also to reach a kind of entanglement, a 'feeling' for the instrument, a skill that is hard to verbalize and instruct. In moments of failure, socio-material relations embedded and embodied in particular practices tend to become visible (Lorenz-Meyer 2014).

20. 3. METHODOLOGY

20.1 Empirical design and analysis

Data collection for this study took place in two different laboratory contexts at university level, one in nuclear physics and one in a genetic engineering course. In order to 'get sight of' the human-material intra-activity as well as the overarching intentions and beliefs of people involved in the activities, we used three complementary methods; observations through video, micro-interviews and individual interviews. The video recording focused on the intra-action between students and the instruments/material/equipment they handled; intra-actions between students and lab assistants; intra-actions between students and lab-instructions. Micro-interviews were performed during the lab sessions where we asked the participants questions about their activities or possible emotions that emerged.

In the nuclear physics laboratory, 37 male and 19 female students worked one day (eight hours) in the lab. The students were supposed to use a gamma-spectrometer to produce a plot with peaks in order to identify some radioactive material. In the genetic engineering course, 25 students with equal gender distribution, had a four-day laboration with the purpose to alter bacteria genome using many different biochemical methods. In both cases, the students were expected to produce a lab report to be assessed. The data material consists of 40 hours of video-recordings, micro-interviews, and complementary field notes for each of the two laboratories.

During analysis of the video-recordings, micro-interviews, and field notes, we used Barad's concept of intra-action to look for entanglements between student-student-lab-assistants-instruments-emotions-gender-communication (Barad 2007). The second step was to highlight similarities and differences between our two different lab contexts, a method described by Barad 2007 to find patterns and objects in webs of intra-actions. In the third step we picked two situations to illustrate results from the analysis and discuss it together with the theoretical concepts. In this step we use Ahmeds politics of emotions to identify how emotions interplay with instructions, materials, and students.

21. RESULTS

21.1 Crowded spaces crammed with artefacts

Vignette 1: The laboratory of genetic engineering is crowded with students working in pairs at a long bench meant for two groups. Various types of materials and equipment are spread across the bench, on the shelves above, and on the floor – some of which the students need to use and handle. Due to the dense material arrangement, students spend a significant amount of time searching for the equipment or apparatus they need. Students use around 80 artifacts during the lab session. They have a detailed lab manual that they meticulously follow. Occasionally, the teachers supplement or adjust the instructions by writing new ones on a whiteboard.

There are many different activities during these lab days. One common recurring task is pipetting various samples into different sets of test tubes. Sometimes, students need to make calculations to determine the volumes to be pipetted, and the different test tubes must be labelled with markers to keep track of the samples. Simple mistakes can have significant consequences on the results. For example, several students mistakenly use the wrong disposable tips for the automated pipettes because they are unaware of the volume variations. This results in incorrect concentrations of the reaction mixtures, rendering them ineffective.

Vignette 2: The laboratory equipment in the nuclear physics lab is arranged on tables with two chairs at each unit. As soon as the students enter the room, they pair up and position themselves at the equipment. Throughout the entire lab session, most students stay at their assigned stations and do not interact with other classmates. However, during one instance observed, six students gathered around a lab unit to discuss what was happening there.

The equipment consists of a computer, an oscilloscope, and a rack with knobs, buttons, and sockets. One part of the rack contains an amplifier, while another part contains high voltage components. There is also a stand where radioactive material can be placed, along with a detector that can be plugged into the oscilloscope or rack. Thick lead plates are arranged around the detector and stand. Various types of cables are also available.

In the room, there is a blue cabinet with warning text indicating the presence of radioactive material to be used in the experiment. The material should not be used longer than necessary, and students may need assistance from the teacher to locate the appropriate material in the cabinet.

In both settings, students are expected to explore and decipher the functionality of the instruments and all the materials themselves, without extensive instructions. Students must sort through the impressions to decide how much of the instruments and materials they will attempt to understand and at what level. Instruments that do not need to be understood in detail function as black boxes. In the cramped genetic engineering lab, the students meet regularly between the groups, discuss and ask each other questions in order to move forward with their experiments. This differs from the physics setting, where students are assigned to stations with limited interaction between different pairs. However, some groups challenge these boundaries, engaging in collective discussions and knowledge-sharing. This boundary-crossing demonstrates an assertion of agency and a desire for collaboration.

21.2 Human bodies-material-emotions-learning intra-actions

Vignette 3: There are two electrophoresis apparatuses in the lab, used to separate and visualise the bacteria DNA-fragments. The students queue up to apply their DNA-samples. Teacher Doris stands by one electrophoresis apparatus and supports the students when needed. The apparatus contains a prepared gel with small wells, where the students need to insert their automated pipette tips and press down their samples to sink them into the wells. The student must handle the pipette with skill, to not disrupt the sample. The transparent gel is immersed in a liquid bath, making it difficult to see the wells, unless viewed from above at the correct angle. Doris instructs the students how to lean against the apparatus to provide support and minimize the risk of shaking. The heads of the students and Doris touch each other as they try to achieve the correct angle to clearly see the wells. The students' faces are focused during this moment and do not express any specific emotions, but some of them exhale loudly when the sample has been applied. Several agents are entangled in this situation: The student's body positioned correctly, the automatic pipette containing a tiny DNA sample; the student's questions to Doris answered with words but also physically as Doris moves her head close to the student to see what the student sees.

A device initially entangled with emotions is the centrifuge, that students are instructed to balance. An imbalanced centrifuge can potentially damage expensive equipment and cause harm. The proper balancing of the centrifuge is a recurring concern. The students express fear that they haven't done it correctly. They also listen attentively for sounds of malfunction, as the teachers have advised them to switch the centrifuge off if they hear if something is wrong. In the end of the week the students' fear diminishes, and they swiftly handle the centrifuge without further discussion. At this point the students master the instrument, and the centrifuge is no longer intra-acting with students' emotions.

Vignette 4: Only a few instructions are provided for the nuclear lab. The teacher gives every student pair some short introductions and announces that they are free to tinkle, except not exceed a given level of the high voltage.

Initially, the students try to understand and learn the instrument. They experiment by turning various knobs and connecting cables. Several students, like Rahid, express frustration as time passes without providing meaningful knowledge: "[The worst part of the activity was the] first two hours when we don't know what to do. What is the meaning of this! So, those two hours were so difficult." However, when they gain knowledge and successfully produce desired outcomes, as peaks on the computer screen, other feelings come in to play: "Best feeling [during the practical activity] when I finally find out that this is actually easy."

Various materials including lead and alpha radiation shape rules and regulations in the physics experimental hall, as eating and drinking are prohibited due to the handling of potentially harmful substances. These rules, dictated by the authorities, take part in regulating students' emotions. For instance, student Malva expressed intense sounds of fear while carrying the radioactive material. At a first glimpse, it seemed as if she really was afraid, but during the interview it becomes clear that she uses her feelings as a tool to remind herself and keep her attention to the potential dangers:

> "I find it very alarming because I don't think about them being radioactive. I would easily just grab that [radioactive substance] if no one had told me it's dangerous."
>
> Her lab partner, Valle, responds:
>
> "Which is locked in a cabinet!" pointing out that the locker should indicate the danger.
> To which Malva responds:
>
> "I know, but I still don't feel scared about it."

Vignettes 3 and 4 show examples of how handling different instruments is an intertwined learning process that includes bodily knowledge and emotions. The situations contain many moments that must be mastered, including different types of emotions. The centrifuge creates fear, a feeling that gradually fades as the students become more confident. In the nuclear physics lab, on the other hand, Malva shows how she generates the feeling of fear to alert herself to the risky lab situation of handling radioactive material.

22. DISCUSSION

In our examples the laboratories are crammed with artefacts. The student must distinguish what artefacts they should use or not and at which level of understanding. The instruments that don’t require detailed understanding, are blackboxed as in the situation with the centrifuge. In accordance with agential realism, (Barad 2007) the boundaries around the blackboxed material are not fixed, in time and space, nor are they the same for all students. An apparatus that is initially used casually may require better understanding later for the students to continue their practical work. Students need skills in actively handling the instruments but also in actively ignoring irrelevant artefacts or details. For teachers who are used to the experimental hall, those artefacts are taken for granted, and therefore there is no explicit instruction about what the students should pay attention to and not. The ability to efficiently make sense of the milieu gives agency to the student in their own learning process. Therefore, it’s important to thoughtfully address taken-for-granted knowledge of instruments and material.

In the nuclear measurements setup, the task is to produce results on a computer screen. Everything before that moment is completely new to the students, so they depend on the teachers. The students express this low agency as boredom and waste of time. In the end of the lab, the students can connect the results to the theory they have learned. This part, as they experienced agency, they refer to as the best part of the lab.

In the vignettes, students’ emotions are constantly intra-actively negotiated and shape the practical activity in many different ways, in line with Ahmed (2004/2012). As an example, Malva uses fear as a tool for proper handling of radioactive materials and student use feelings of meaning or boredom for seeking agency. Teachers have agency in this entanglement, in scaffolding the students.

In a broader sense, emotions are entangled with the process of becoming part of the community of practice (Lave & Wenger, 1991). The results from the nuclear measurements setup suggest that emotions play a role in shaping students' perceptions of their own agency and the value of their learning experiences. They also suggest that agency and empowerment are contingent on the ability to make meaningful connections between theory, instruments, and material outcomes. As discussed by Berge et al. (2019) the tinkering student, has an advantage in the integration into the community. Feelings of lust lead to tinkering. Tinkering creates feelings of lust in case of success. If the students don’t have enough knowledge and skill to succeed this can create feelings of frustration. Frustration in itself can lead to either motivation to continue or to alienation.

Overall, this analysis through the lens of agential realism highlights the entanglement of materialities, student agency, and knowledge production. It underscores the importance of recognizing the active role of both human and non-human entities in shaping educational experiences and the formation of knowledge in engineering education.

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Exploring the Use of Peer and Self-Assessment as a Pedagogical Tool in UK Secondary Design Education.

Andrew Halliwell, University of Cambridge, Ajth4@cam.ac.uk

ABSTRACT

In this case study, a collaborative and social-constructivist approach to secondary Design and Technology teaching is explored. Self and peer-assessment interventions are employed as a pedagogical tool for increasing student attainment, knowledge gain and self-efficacy. Within schools, students learn by interacting with their peers; they help each other identify their strengths, address their weaknesses, and develop metacognitive skills. As a construct for aiding knowledge sharing, peer assessment can be significantly beneficial as it allows students to evaluate the work of their peers and provide constructive feedback within a supported environment. This research presents student perceptions on strategies designed to facilitate self-assessment, and peer-assessment as a pedagogical tool and investigates the order these strategies are employed within the classroom. Eighteen, year 11 design students aged 15-16 from across two classes took part in four 'peer-learning' sessions containing both self and peer-assessments. These sessions were spread across different stages of the student's design process: research, iteration, design development and testing and evaluation. The project began at the start of the 2022-23 academic year and concluded at the end of the second term. Each session approaches these assessment exercises with different methods and finishes with a questionnaire to enable comparison. The results gathered show an increase in student attainment, self-efficacy, and a greater understanding of the assessment criteria when students complete their design coursework. A sequence of activities for employing self and peer-assessment within design education is established and presented. This research aims to share evidence of self and peer-assessment as a pedagogical tool when students are completing their design coursework. In presenting the benefits and barriers of this method, teachers will be able to use and adapt it within their own classes.

Keywords: Peer Assessment, Peer Learning, Pedagogy, Action Research, Secondary Design Education.

1. INTRODUCTION

23.1 Context

The research reported here is part of a pilot study for a larger educational doctorate project. The doctoral project explores the influence of collaborative learning curriculum on student creativity and attainment with year 11 students. As a result, the study reports on the contextual application of SA and PA and only documents the views of the students within the study school, however, it aims to provide guidance for secondary design teachers to follow. As a teacher-researcher, my interest in this research topic stemmed from observing students produce coursework that missed the finer details in the mark scheme. I was frustrated that my feedback focused on simple mistakes and the standard of students' first submission was below expectation. To address these issues, I explored self-assessment (SA) and peer-assessment (PA) as a pedagogical tool for increasing student attainment, knowledge sharing and self-efficacy. Presented in this paper are the strategies I employed to scaffold student SA and PA activities as part of the pilot for the larger project.

23.2 Learning is social.

Within secondary education, marking and providing feedback on several iterations of students work consumes considerable amounts of teachers time and has been documented as a significant contributor towards teacher stress and burnout (Brady & Wilson, 2021). Research by Harrison et al. (2015) demonstrates that traditional teacher assessment methods can hinder the development of independent learners. Instead, the authors advocate the use of SA and PA strategies to increase self-awareness and reflection amongst students, which they argue are essential components of self-efficacy. Furthermore, research that has involved students in their own learning highlights an improvement in their academic performance, ability to share knowledge and cognitive skills (Andrade, 2019; Davies, 2002). For Neo (2003), placing students within learning environments, where they learn from each other, provides opportunities for optimal intellectual and academic development. In this way, knowledge is the product of social negotiation and discussion with others. This is also further described by Pozzi et al. (2007) as 'the primary way to learn' as it promotes critical thinking and understanding. A learner-centred approach that focuses on the processes rather than the products of student learning is, therefore, proposed and explored (Lobato, 2003).

24. LITERATURE REVIEW

SA and PA activities have gained prominence in educational settings as effective strategies for involving students in their own learning and providing transparency to the assessment criteria (Panadero et al., 2013). SA involves learners making judgements about their own learning by describing their perceived progress or result with the purpose of generating feedback that promotes student learning (Andrade, 2019). Butler and Winne (1995) proposed that feedback is an 'inherent catalyst' of self-regulation; as students reflect on their progress, internal feedback is generated which describes the students' qualities of the outcomes and cognitive processes (p. 245). In this way, Brown and Harris (2013) define SA as a "descriptive and evaluative act carried out by the student concerning their work and academic abilities" (p. 368). When concerned with the reliability and validity of student SA Tejeiro et al. (2012) highlighted that student and teacher assessments are commonly not aligned when the student SA contributes towards their overall grade. This is, however, not representative of a learning activity that uses SA for feedback. Conversely, when SA is used for learning and feedback, studies have demonstrated that it shares comparable accuracy with external assessors (Andrade, 2019).

Unsurprisingly within classrooms, SA and PA are available in large quantities and can be accessed more directly than teacher feedback (Topping, 2017). Here, peer-assessment is viewed as a form of collaborative learning whereby students use criteria to evaluate the work of their peers and provide specific feedback and/or a grade (Alt & Raichel, 2018). For effective PA feedback to be given and for assessments to be reliable, Topping (2017) argues that training, checklists, examples and practice are required. Immediate practice of PA is essential; feedback and coaching from teachers should concentrate on students' thinking and justification by modelling sound reasoning, effective use of evidence and clear explanations (Brookhart, 2010). Students who doubt the efficacy of themselves or their peers when participating in PA may leave students feeling dissatisfied with the process (Alt & Raichel, 2020). This aligns with Van Zundert et al. (2010) who highlighted an increase in students domain-specific skills and attitudes towards PA when trained and experienced peer assessors provided feedback. To avoid the problem of inter social tensions, Davies (2002) calls for anonymity during PA to remove the bias from friendships, uniformity and race. Online PA is advocated by Lu and Law (2012) as a means of enabling students to mark, feedback and critique the work of peers anonymously. Working online allows teachers to oversee students' participation and progress in real time (Topping, 2018). If quality feedback is to be provided, students need to be able to comment freely on the work of others without the risk of reprisal (Bhalerao & Ward, 2001).

Davies (2002) notes that a crucial facet of PA is ensuring all students complete their marking thoroughly and offer constructive feedback to their peers. Similarly, it is important that students approach SA in a reflective and objective manner. For this to occur, Topping (2018) argues that students need to have a clear understanding of the assessment criteria that will be used to evaluate their work. This in turn will help students to become independent and reflective thinkers. Moreover, Topping proposes that students are more engaged and have greater clarity of the assessment criteria when they have helped to develop it, with many teachers supporting the use of assessment rubrics for scaffolding student interactions (p. 68).

In summary, whilst both SA and PA do not come without their difficulties, there are many educational benefits for students. This study explores strategies for implementing SA and PA within a secondary D&T classroom setting and the benefits for doing so.

25. METHODOLOGY

Within both SA and PA, learning is an active process of meaning-making where individuals create their own understanding by drawing on their own experiences (James, 2008). Constructivist learning environments align with SA and PA as they build on students' prior knowledge by encouraging enquiry, collaboration and focus on interactive learning (Kritikos et al., 2011). As a teacher-researcher exploring practice within my own classroom, I adopted a case study methodology with a social constructivist epistemology (Cohen et al., 2018). I am a design and technology teacher at the study school. The students involved in the study are from my classes, which I see three times a week. Due to my active involvement in the study, for clarity and consistency, I refer to myself as 'the teacher' when describing the study and its findings. The study adopted a quantitative approach towards research design with the purpose of answering the following research questions:

(i) What are students' perceptions on the value of strategies designed to facilitate SA and PA activities?
(ii) How do strategies designed to facilitate SA and PA activities influence student attainment and self-efficacy?

25.1 Participants, Research Context and Ethical Consideration

The study was formed of 18 Design and Technology (D&T) students (seven girls and 11 boys) aged 15-16, from two classes. The research took place at one independent boarding school during the 2022-23 academic year. It's important to note that the study school facilitates its own courses equivalent to that of GCSE's. Consequently, the school is not bound by the national curriculum for the D&T GCSE (Department for Education, 2015).

As agreed by the school, the study was conducted within the normal lessons of the school's own course. Student participation was only voluntary in the data collection activities, where they were reminded of their right to withdraw at any time. The study conformed to the guidelines set out by the British Educational Research Association (BERA, 2018) and was ethically approved by the University of Cambridge.

25.2 The Study

All students completed one design project across two terms as part of their D&T course. During this project, the participants completed four 'peer-learning' sessions, involving both SA and PA. These were spread out over the research, design, development, and testing and evaluating stages of the design process. At the start of each session, the teacher guided students through the assessment process by talking through examples of their own marking (teacher training) and provided additional marked examples for students to refer to as master reference sources (Topping, 2018). At the end of each session, each student had a SA, PA, and their teacher's assessment for the same piece of work. Providing teacher feedback aimed to re-affirm grade criteria and provide a direct comparison of student/teacher assessment standards. Any marking of student work conducted by me followed the assessment criteria established by the study school and was moderated by the head of the design department.

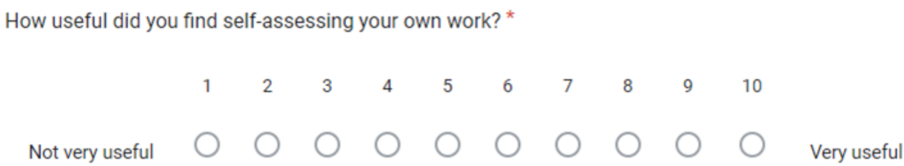
To mitigate any issues over students providing feedback for each other, all student work was anonymised and distributed randomly to students in the other class. Questionnaires were then completed by all students following each session to document their thought and learning progression. To explore SA and PA pedagogical strategies, the activities and format of each session changed. In session two and three students created their own mark scheme whereas session one and four used the schools' assessment criteria. Session two and four conducted assessment practice with students before they started the next section of the design process, however, session three completed it afterwards. The outline of each session can be seen in Table 1.

Table 8:
Contents of the Peer-Learning Study Sessions

Peer Learning Session	Teacher Training	Mark Scheme Created	Assessor Practice Before	Assessor Practice Afterwards	SA	PA	Teacher Marking
1. Research	✓	✗	✗	✗	✓	✓	✓
2. Design	✓	✓	✓	✗	✓	✓	✓
3. Development	✓	✓	✗	✓	✓	✓	✓
4. Testing and Evaluating	✓	✗	✓	✗	✓	✓	✓

To gather the views of the students, questionnaires were employed as the data collection method with closed and 10-point rating scale questions (Coe et al., 2021). The rating scale questions aimed to document students' thought progression over time, for an example, see in Figure 1.

Figure 15:
Questionnaire rating scale example.



Within small class sizes the range of responses can be broad; the median has been employed as the measure for identifying the central tendency within the data due to its resilience from outliers within a distribution. This is achieved by identifying the dividing point in a response range so an equal number of scores are above and below that point (McCall, 1970). Aligning with a quantitative research design, this was conducted through a positivist view (Cohen et al., 2018). The findings present and compare the median scores of student responses from across the four questionnaires.

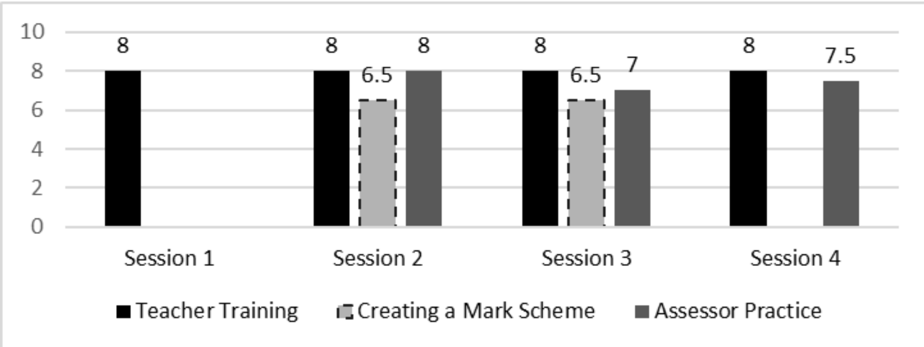
26. RESULTS AND DISCUSSION

In this section an overview of the results gathered from the four questionnaires in relation to the two research questions is given. A brief discussion regarding the implications of these results is also presented. In what follows, the medians (M1), (M2), (M3), (M4) relate to the range of results gathered from the questionnaires from sessions one, two, three and four respectively. This data has been calculated and presented in the appropriate figures below.

26.1 What are students' perceptions on the value of strategies designed to facilitate SA and PA activities?

As highlighted in Table 1, each session incorporated different pedagogical strategies for facilitating and preparing students to conduct SA's and PA's. At the end of each session students were asked to identify how useful, they thought, each activity was to their learning. Three strategies were explored: teacher training (the teacher talking through and explaining their marking process with examples), creating a mark scheme (as a class producing a mark scheme based on the schools' assessment criteria) and assessor practice (completing practice PA's and comparing feedback and grades with the teacher's assessment for the same piece of work), see Figure 2.

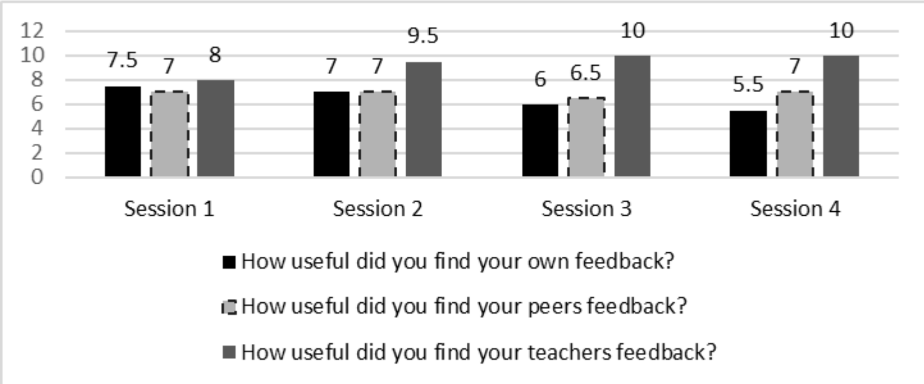
Figure 16:
Usefulness of SA and PA strategies to Student Learning



The results show strong and consistent favour towards teacher training with a median score across all four sessions returning an eight. Practicing assessment was equally valued highly by students, although, the lowest median (M3) of seven was produced when students practiced assessing work after they had completed the relevant page. Lastly, creating a mark scheme remained at six and a half which suggests that although some students found it to be beneficial it was not as useful as the other strategies.

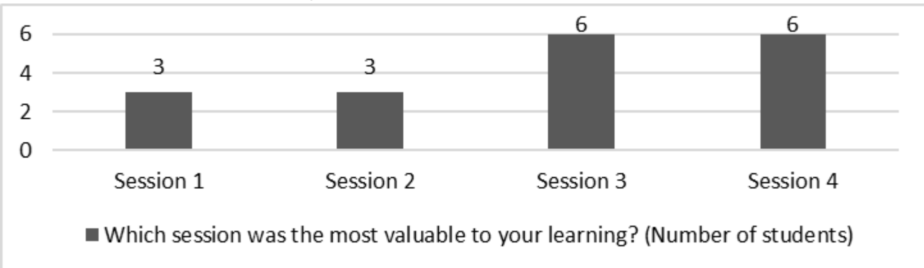
Noted within the literature is the importance of students being able to both give and understand constructive feedback. When asked about how useful students found their own, peer's and my teacher feedback, they returned the following results: see Figure 3.

Figure 17:
Student Views on Feedback



As the sessions progressed the teacher feedback increased from M1 (8) to M4 (10). The usefulness of peer feedback remained within 0.5 of each median score. The usefulness of students' own feedback decreased with each session from M1 (7.5) to M4 (5.5). This may be the result of the repeated learning activities teaching students to identify and internalise the areas they need to improve without writing their feedback down. To further investigate the benefits and sequence of the pedagogical strategies, students were questioned on how valuable they thought each session was to their learning. At the end of the fourth session, students were then asked to identify which of the four had been the most valuable to their learning, see Figure 4.

Figure 18:
Session Value to Students Learning

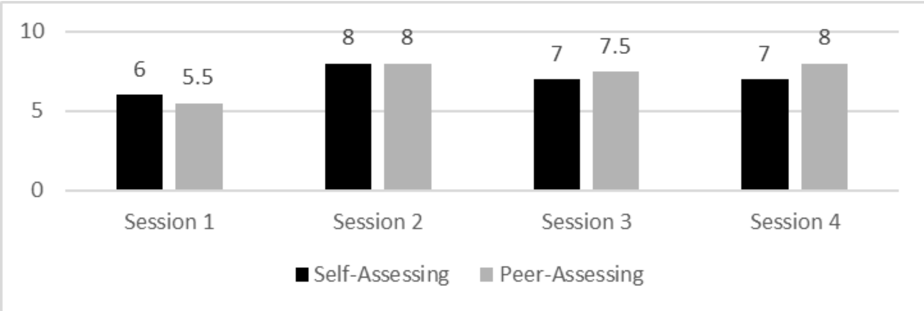


The results returned no favour towards any particular sequence of activities. 50% of the students' selected sessions that included creating a mark scheme to be the most valuable to their learning. It is important to note, however, that creating a mark scheme in addition to assessor practice running after students had completed the page (Session three) was scored equally with only completing assessor practice before students started their work (Session four).

26.2 How do strategies designed to facilitate SA and PA activities influence student attainment and self-efficacy?

To investigate changes in self-efficacy, students were asked to identify how confident they felt, following each session, at self-assessing and peer-assessing coursework; the median scores are shown in Figure 5.

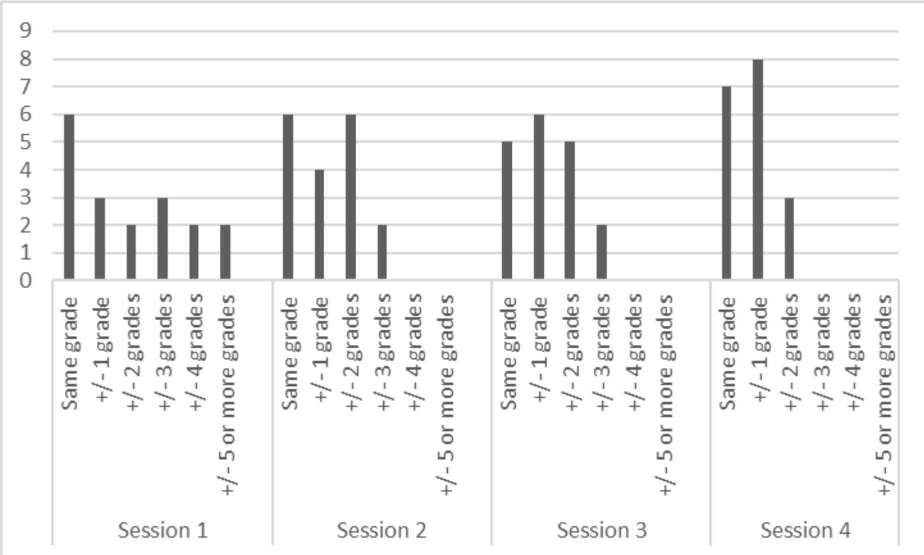
Figure 19:
Students Confidence When Completing SA's and PA's.



Presented within the results is an increase in student confidence when completing both SA's and PA's between sessions one and two. Whilst all sessions involved the teacher discussing their thought process when marking work, session two was the first to include assessor practice and mark scheme creation. Doing so saw an increase in student confidence for both SA and PA from M1 (6) to M2 (8) and M1 (5.5) to M2 (8) respectively. The findings also highlight that students have greater confidence when marking and providing feedback for their peers than their own work; this aligns with the findings from Figure 3.

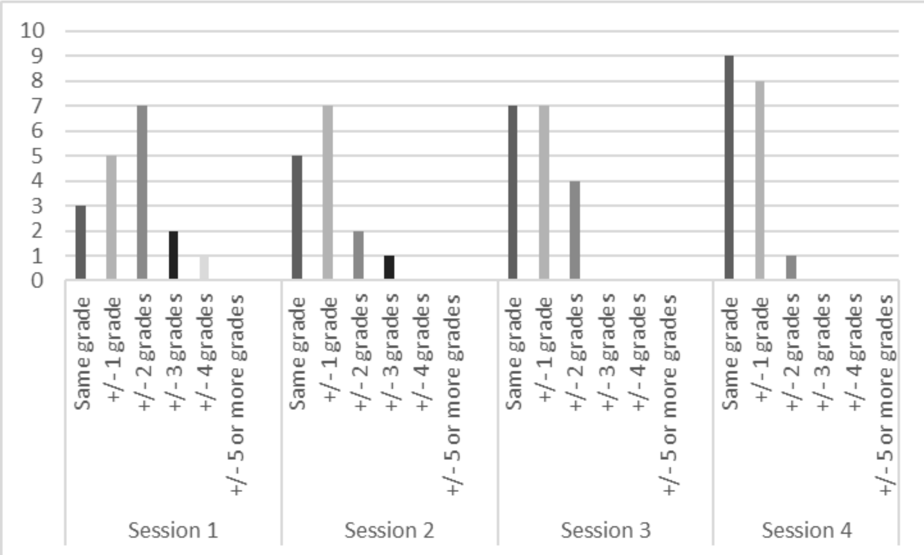
To explore the accuracy and reliability of student SA and PA, in each questionnaire students were asked to identify how close the grade they awarded themselves was in comparison to the one awarded by their peer. Highlighted from the results is that as the sessions progressed so did the accuracy of the self-assessed and peer-assessed grades. Whilst nine of the 18 students were within one grade of their peer's grade in the first session, by the fourth session this had grown to 15. At the other end of the scale, a significant change can be seen from those students who were three or more grades away from their peer. In session one this included seven students, at the end of session two this had dropped to two and by session four did not include any. The results from each session are displayed in Figure 6.

Figure 20:
SA and PA Grade Comparison



A similar trend can be seen when comparing SA grades with the grade awarded by the teacher; see Figure 7.

Figure 21:
SA and Teacher Assessed Grade Comparison



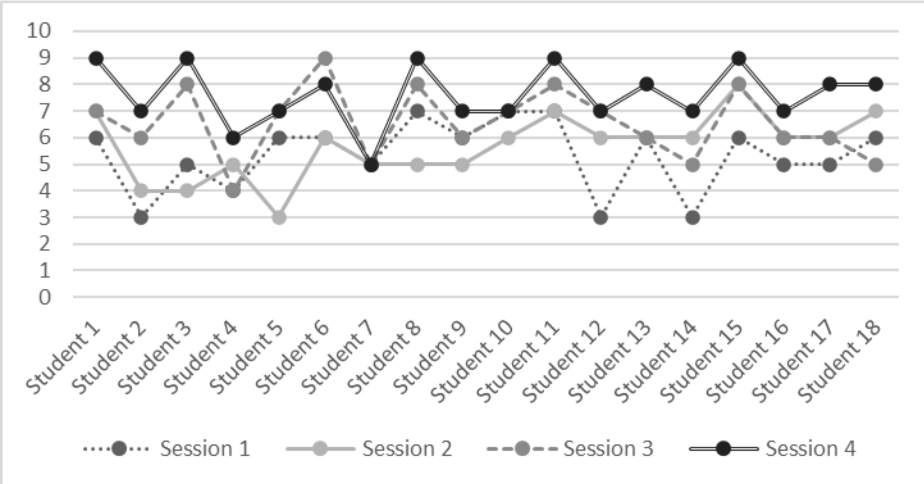
As the sessions progress there is a clear improvement in the accuracy of student awarded grades with the teachers. From session one to four this went from eight students being within two or more grades to 17. Like the results in Figure 6, there was a notable change between session one and two where the number of students who were two or more grades out decreased from 10 to three.

To further investigate the changes in student attainment, the grades awarded for each student across the four sessions was documented and are presented in Figure 8 and Table 2. Whilst these grades were initially awarded by me using the school's marking criteria, they were also moderated by the head of the design department.

Table 9: Moderated Teacher Awarded Grades

Grades awarded from	Individual students																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Session 1	6	3	5	4	6	6	5	7	6	7	7	3	6	3	6	5	5	6
Session 2	7	4	4	5	3	6	5	5	5	6	7	6	6	6	8	6	6	7
Session 3	7	6	8	4	7	9	5	8	6	7	8	7	6	5	8	6	6	5
Session 4	9	7	9	6	7	8	5	9	7	7	9	7	8	7	9	7	8	8

Figure 22:
Moderated Teacher Awarded Grades – Visual Representation



The median results for each session show an increase in student attainment with the most notable being between session three and four: M1 (6), M2 (6), M3 (6.5), M4 (7.5). These results suggest that although individual activities may be valued by the students, it is the repetition of SA, PA and their associated activities that has produced an increase in student attainment.

27. CONCLUSION

Whilst there are benefits to creating a mark scheme with assessor training and practice, it is apparent that the frequency of these activities, is important. Aligning with Topping (2018) I agree that students require training over a number of sessions for SA and PA to be both effective and worthwhile. From this study, I propose to other practitioners that are considering incorporating peer learning into their classrooms the following: First, a student created mark scheme should be completed at the start of the lesson sequence and continually referred to instead of being remade for each session. Second, assessor practice should be conducted both before and after students complete their work and alongside the teacher talking through examples of their marking. Finally, teachers must provide their own marks and feedback for students to compare against. It is this structure that I will employ within my larger doctoral study.

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Redesigning the Design and Technology Curriculum in England: Led by Teachers

Andrew Halliwell, University of Cambridge, Ajth4@cam.ac.uk
Amanda Mason, Jarrow School, amandamason12@hotmail.co.uk
Alison Hardy, Nottingham Trent University, alison.hardy@ntu.ac.uk
Ciaran Ellis, Laurus Ryecroft School, ciaran.ellis@laurusryecroft.org.uk

ABSTRACT

It is regularly reported at previous PATT conferences that design and technology (D&T) in England is in decline. Despite initiatives, new curricula and government lobbying, the D&T juggernaut seems to be on the brink of collapse (according to some), with lowering numbers of pupils studying D&T, fewer teachers, less resources, and low status in schools.

Pulling the D&T juggernaut back from the brink requires more than one approach and most of the recent ones have been led by national organisations. This paper reports on the first phase of a new project, led by practising teachers, that takes a new approach. In simple terms, the aim of the project is to redesign D&T, not so much the content but the curriculum delivery and framework.

We have started by identifying the unresolved issues that are causing curriculum tensions and incoherence in the D&T community.

In this paper we are reporting on the first phase of our design project, where we used a Delphi Study to identify the controversial D&T curriculum issues that need resolving before we can design a D&T curriculum. Nineteen teachers completed the first survey. Analysing of the survey data reduced the number of questions to 24. These were circulated to a self-selecting expert group (participants who completed the first survey). A second round of analysis has clarified that there are 18 unresolved questions and contentions issues that need to be debated.

The next step is to invite teachers to respond to these issues; these responses will then be shared in a publication, debated, and shaped into a curriculum design specification. Finally, teachers will be invited to share at a future workshop or conference their curriculum design ideas that meet this specification.

Keywords: curriculum, teacher researcher, practitioner researcher, Delphi Study.

1. INTRODUCTION

It is regularly reported at previous PATT conferences that design and technology (D&T) in England is in decline (e.g., Hardy, A. et al., 2015; Martin, 2012; Vickery, 2022). (Hardy, Alison, 2021; Hardy, Alison L., 2017; Hardy, Alison L., 2018). Whilst student entries for D&T have been in decline since 2001, when the subject became non-compulsory at key stage 4, there has been a significant decline within the past decade. GCSE candidates have dropped by 72% from 2010 (277,701) to 2022 (77,531) and in the same period, A-Level numbers have dropped by 38% from 18,417 to 11,404 (Joint Council for Qualifications, 2023). Despite policy initiatives, such as including creating a new performance measure - 'Progress 8', there has been no observed reversal in this decline; implying that there are wider issues impacting the uptake of the subject. Simultaneously, the shortage of qualified teachers within the field only exacerbates this issue. The Education Policy Institute highlights that the number of qualified D&T teachers reduced from 6% to 3% of all teachers from 2011 to 2020 with D&T recruitment only meeting 23% of its overall target in 2021/22 (EPI, 2022). The scarcity of expertise within schools undermines the potential growth of the subject and hinders its ability to meet the pupils' and societies needs from education.

The subject is now commonly discussed in association with declining student enrolment numbers and shortages of qualified teaching staff (DATA, 2022). This trend is of great concern amongst educators and industry professionals as it raises questions about whether the current curriculum of D&T is adequately preparing students with the skills and competencies they will need in the workplace (Meyer & Norman, 2020) and beyond.

Notably, creativity has emerged as a crucial focus in education, particularly within the context of 21st century learning and is widely recognised to be central to the subject. (Collard & Looney, 2014; Spendlove & Hopper, 2004).

This has led to discussions about if the current English D&T curriculum is fit for purpose (Spendlove, 2021; 2022). If not, should the design of a new curriculum be led by politicians, policy writers and non-practising teachers (e.g., academics who are researchers) or by the practising teacher community (Norman, 2021)? Our view is that it is time for practising teachers to not only be consulted but to lead the consultation and (any) redesign. This idea aligns with Phil Roberts' (2001) support for teachers-as-researchers and has led to a small group of D&T teachers, supported by an academic, to lead a design project 'Redesigning D&T'.

This project was first mooted in the book "Redesigning D&T … Talking … Thinking" (Hardy, Alison & Norman, 2021) and ended with a call to action for the development of first a design specification for a new curriculum, which would lead to a new D&T curriculum. Norman (2021, p.108) argues that "teachers' reflections on the direction that designing in schools should take could [should?] plan a fundamental role in the subject's reform".

Recently developments by Pearson's exam board (2023) and the Design and Technology Association (2022) have invited teachers to be involved in contributing to their ideas but both have been led by the organisations; the Redesigning D&T project, whilst instigated by an academic is now led by three practising teachers, with the academic facilitating the process and supporting with ethics and funding opportunities.

1.1. A DEVELOPING PROJECT: INVESTIGATING FUTURE FORMS OF DESIGN AND TECHNOLOGY EDUCATION

1.1.1. Project Aim

The aim of the study is to design a new D&T curriculum for teaching in England to primary and secondary schools. We aim to develop D&T curriculum through consensus using a design-based approach. We are not so much focussing on the curriculum content, but on the curriculum design, implementation, and framing of the curriculum.

1.1.2. Project phases

Using the Delphi technique (Keeney et al., 2011), the Redesigning D&T project aims to develop the D&T curriculum for teaching in England to primary and secondary schools through the consensus of members of the D&T teaching community. To achieve this aim there are several phases:

- Phase 1: Identification of the big or controversial D&T curriculum issues (COMPLETED).
- Phase 2: Debating the controversial D&T curriculum issues and reaching consensus (IN PROGRESS).
- Phase 3: Designing and evaluating curriculum solutions in response to the consensus.
- Phase 4: Agreeing on a new D&T curriculum.

In the first phase there were two rounds:

- In round 1 members of the D&T teaching community to respond to a survey detailing some big or controversial D&T curriculum issues identified by two academics (Alison Hardy and Eddie Norman). Responses were collected via Qualtrics, and participants were invited to form an expert group and or join the project team.
- In round 2 the self-identified expert group responded to a questionnaire (also on Qualtrics), where they were asked to prioritise the issues identified in round 1.

This paper reports on phase 1 only and concludes with a description of the next phase which we started in July 2023. We will report on some of the preliminary findings from phase 2 at the conference in November.

1.1.3. Project team

Initially eight teachers indicated they would be part of the project team, but due to other commitments this has now become three teachers leading the project: Ciaran Ellis, Andrew Halliwell and Amanda Mason. Alison Hardy continues to facilitate, providing research guidance and leading on the ethics applications (processed via Nottingham Trent University).

2. PHASE 1, ROUND 1

Participants in the first-round were presented with a list of questions. These were determined before the research team was formed but seen as challenges D&T faced, questions that still need answering, or is still being debated, or where there is no clear response. The first round of questions were put to the public via social media and through Alison Hardy's podcast. Here, it was also explained the purpose behind the research project, alongside the initial list of potential questions (Figure 1). The aim of this first round was to form a consensus on which questions were to be used for the final round of phase 1 and for phase 2.

Figure 1
Controversial questions (Phase 1 Round 1)

Nature of D&T
1.D&T is a vocational subject
2.Should the subject be called 'design' or 'design and technology'?
3.What's the technology in design and technology?
4.Does D&T actually make a difference to industry?
5.Do designers know anything?
6. D&T is not an inclusive subject

Content
7. Design: is it art or technology or science or humanities?
8. Craft has no place in D&T
9. Is there design knowledge?
10. What is interdisciplinary knowledge?
11. Is making vital to D&T?
12. Is there a design process?
13. Has science got anything to do with D&T?
14. What is design thinking?
15. What do values have to do with D&T?
16. Are textiles just another material in D&T?
17. Are some materials more important than others in D&T?
18. Are materials just another technology?

Learning and assessment
19. Do children need to be skilful makers and modellers?
20. Should children make what they design?
21. Can you start a D&T project without knowing anything?
22. Should children be taught cognitive modelling?
23. Do we teach skills in D&T? What do we mean by skills in D&T?
24. Do you need a workshop? Or any specialist space?
25. Is the outcome more important than the process?
26. Can we assess design?

The survey structure followed the Delphi process (Keeney et al., 2011) and the participants were asked to:

(iii) identify which questions agreed needed to be debated.
(iv) identify which questions they disagreed and felt did not need to be discussed.
(v) detail any questions they considered had been missed from the list.

Unfortunately, the responses to this last question indicated a confusion about the purpose of the survey, resulting in many participants writing answers to the questions. For example:

> "Do children need to be skilful makers and modellers [question 19]
>
> There is too much emphasis on the perfection and making something that works... there needs to be about the process - like in mathematics - it is not answer that gets the mark - it is the process."

Finally, participants were also asked if they would like to be more involved with the project and or would promote the survey to others (i.e. snowball sampling (Braun & Clarke, 2013)). Those who wanted to join the project team were invited to an initial meeting with Alison Hardy who explained the project in more detail and the teachers identified which part of the project they wanted to be involved in (e.g., data analysis, project promotion or publications).

The survey data was then shared with the data analysis team. From the 22 responses, 6 replied no to each answer and offered no further suggestions to which questions should or should not stay for the next round. The data team then decided on which questions were to stay. There was consensus that question 1 and 9 (Figure 1) were to remain and was a question that still needed debating, alongside questions, 2, 4, 8, 11, and 12. Other questions, although with a smaller number of responses naming them were questions, 3, 7, 13, 14, 16, 17, 19, 20, 21, 22, 23, 25 and 26.

The data team discussed the wording of some of the questions. For example:

- 'Craft has no place in D&T' seemed a leading statement and so was rephrased to 'Does craft have a place in D&T?'.
- 'Has science got anything to do with D&T?' was re-worded to 'What subjects should be in D&T?'.
- Q16 and 17: it was felt as though these questions seemed to warrant very similar responses and so were merged to create the question 'Are some materials more important than others in D&T?'

Even though some questions were not agreed or disagreed with, the team adjusted the wording:

- Q6 'Is D&T in England Eurocentric?' was changed to 'What does a global D&T curriculum look like?'
- Q10 'What is interdisciplinary knowledge' rephrased to 'Is there a core body or knowledge for D&T or is its knowledge drawn from other disciplines/subjects?'
- Q15 'What values have to do with D&T?' re-worded to Do design decisions involve making value judgements? What do value judgements have to do with D&T?'
- Q18 was removed, it was felt this would be answered in the newly formed question from merging Q16 and 17.

This resulted in the new list of questions that would go forward to round 2 (Figure 2).

Figure 2
Consolidated controversial questions from Phase 1 Round 1

Nature of D&T
1. D&T is a vocational subject 2. What should the subject be called? 3. What's the "technology" in design and technology? 4. What are the technologies in design and technology? 5. Does D&T make a difference to industry? 6. What does a global D&T curriculum look like?
Content
7. Design: is it art or technology or science or humanity? 8.Does craft have a place in D&T? 9.Is there design knowledge? 10.What do we mean by skills in D&T? 11. Is there a core body of knowledge for D&T or is its knowledge drawn from other 12.disciplines/ subjects? 13.Is making vital to D&T? 14.What is design thinking? 15.Do design decisions involve making value judgements? What do value judgements have 16.to do with D&T? 17.Are some materials more important than others in D&T? 18.What subjects should be in D&T?
Learning and assessment
19.Do children need to be skilful makers and modellers? 02.Should children make what they design? 21.Can you start a D&T project without knowing anything? 22.Should children be taught cognitive modelling? 23.Do we teach transferrable skills in D&T? 24.Do you need a workshop? Or any specialist space? 25.Is the outcome more important than the process? 26.Can we assess design?

3. PHASE 1, ROUND 2

In round 2, participants were asked to rate each question, indicating on a Likert scale where that question still needed resolving: "strongly agree" that this would be a question that still needed debating, to "strongly disagree" if they was felt that the question did not need further discussion. This rating systems allowed for the survey to be completed quickly and the data analysis process was different to that used in round 1. The survey was shared with the original 22 respondents to round 1; 9 responded.

Using the cumulative data seemed the most appropriate information to use, as it was clear when using the 70% margin from the Delphi technique, which questions could be used in Phase 2. Using the cumulative percentage data for those who responded "strongly agree", "somewhat agree" and "neither agree or disagree", we determined the questions to be used on Phase 2 would be where the cumulative percentages were 70% and above. Following this rule, we were able to remove questions, 2, 4, 6, 15, 19 and 20 from the list, leaving the finalised list of questions going into phase three of the project, asking for teachers to have their say (Table 1).

Table 1
Phase 1, Round 2 data

				Cumulative				
		Average	STD	Strongly agree	Somewhat agree	Neither agree or disagree	Somewhat disagree	Strongly disagree
1	D&T is a vocational subject	31.22	1.48	22.2%	55.6%	88.9%	100.0%	100.0%
2	What should the subject be called?	30.89	1.54	22.2%	33.3%	55.6%	77.8%	77.8%
3	What is the 'technology' in design and technology?	31.44	1.01	11.1%	55.6%	77.8%	77.8%	77.8%
4	What are the technologies in design and technology?	31.33	1.00	11.1%	44.4%	66.7%	66.7%	66.7%
5	Does D&T make a difference to industry?	32.00	1.00	33.3%	77.8%	88.9%	88.9%	88.9%
6	What does a global D&T curriculum look like?	31.88	0.83	25.0%	62.5%	62.5%	62.5%	62.5%
7	Design: is it art or technology or science or humanity?	31.25	1.67	25.0%	62.5%	75.0%	100.0%	100.0%
8	Does craft have a place in D&T?	31.25	1.39	12.5%	62.5%	87.5%	100.0%	100.0%
9	Is there design knowledge?	32.75	0.46	75.0%	100.0%	100.0%	100.0%	100.0%
10	What do we mean by skills in D&T?	32.63	0.52	62.5%	100.0%	100.0%	100.0%	100.0%
11	Is there a core body of knowledge for D&T or is its knowledge drawn from other disciplines/ subjects?	32.25	1.39	62.5%	87.5%	87.5%	100.0%	100.0%
12	Is making vital to D&T?	32.38	0.74	50.0%	87.5%	87.5%	87.5%	87.5%
13	What is design thinking?	32.25	0.89	50.0%	75.0%	75.0%	75.0%	75.0%
14	Do design decisions involve making value judgements?	31.75	1.04	25.0%	62.5%	75.0%	75.0%	75.0%
15	Are some materials more important than others in D&T?	30.75	1.49	12.5%	37.5%	62.5%	75.0%	75.0%
16	What subjects should be in D&T?	31.75	1.49	37.5%	75.0%	87.5%	100.0%	100.0%
17	Do children need to be skilful makers and modellers?	31.75	1.04	25.0%	62.5%	75.0%	75.0%	75.0%
18	Should children make what they design?	31.25	1.16	12.5%	50.0%	87.5%	87.5%	87.5%
19	Can you start a D&T project without knowing anything?	30.88	1.25	12.5%	25.0%	50.0%	62.5%	62.5%
20	Should children be taught cognitive modelling?	31.50	1.20	12.5%	62.5%	62.5%	75.0%	75.0%
21	Do we teach transferrable skills in D&T?	31.88	1.55	50.0%	75.0%	87.5%	100.0%	100.0%
22	Do you need a workshop? Or any specialist space?	32.38	0.52	37.5%	100.0%	100.0%	100.0%	100.0%
23	Is the outcome more important than the process?	31.38	1.51	25.0%	62.5%	87.5%	100.0%	100.0%
24	Can we assess design?	31.88	1.36	37.5%	75.0%	75.0%	87.5%	87.5%

Figure 3
Final questions for Phase 2

1. D&T is a vocational subject?
2. What does the 'technology' in design and technology?
3. Does D&T make a difference to industry?
4. Design: is it art or technology or science or humanity?
5. Does craft have a place in D&T?
6. Is there design knowledge?
7. What do we mean by skills in D&T?
8. Is there a core body of knowledge for D&T or is its knowledge drawn from other disciplines/ subjects?
9. Is making vital to D&T?
10. What is design thinking?
11. Do design decisions involve making value judgements?
12. Do children need to be skilful makers and modellers?
13. Should children make what they design?
14. Can you start a D&T project without knowing anything?
15. Do we teach transferrable skills in D&T?
16. Do you need a workshop? Or any specialist space?
17. Is the outcome more important than the process?
18. Can we assess design?

4. WHAT'S NEXT?

Now we have finalised the contentious questions, we are circulating them on social media, via mailing lists and through the project team's contacts. In phase 2, we are inviting practising D&T teachers to write, video, record or sketch a response to up to four of the 18 questions. The deadline for the responses is later in 2023, after then the project team will edit and collate them into a publication, which will be available to purchase at a not-for loss rate. Our ambition is to secure funding to host a face-to-face debating day in 2024, bringing together practising teachers to debate and vote on each of the questions, leading to a consensus. This would be the end of Phase 2 and the selected debate for each question would be published as a curriculum design specification. Teachers would then be invited to share their design ideas for this specification. We anticipate the ideas will take the form of a curriculum model, units of work or a framework for planning the curriculum. It is likely that these ideas will already be used already in schools. The idea is not so much to reinvent the D&T curriculum content but more to use the specification to develop existing designs as well as come together to create new ones based on current practices. Then, teachers will be invited to share at a future workshop or conference their curriculum design ideas that meet this specification.

Whether these ideas will lead to an agreed solution is debatable (phase 4), it may be a resolution that teachers take and improve through practice and reflection in their schools.

5. CONCLUSION

New proposals emerging this year have been instigated by key organisations with an invested interest in the survival of D&T (e.g., Pearson's and D&TA). Our project differs in three ways: it is teacher led, the data collection and the data collected are freely available and the consultation process is allowing realistic time for teachers to reflect and share their views then debate with others. Our approach is building on Roberts' call for teachers-as-researchers, and we are taking a measured approach to the project. With seven iterations over 30 years that seem to have 'failed', we are reluctant to rush in with an untested solution. This is an embryonic project and we anticipate that some of our design planning may go awry over the next 12 months, but with interest from the Department for Education and Dedign Council in our phase 2 work, we have motivation to keep the project on track.

We hope that the design ideas suggested by teachers will be seen as resolutions not solutions, the next iteration of D&T (akin to Spendlove's (2021) idea of design and/ or technology 2.0). We hope this project may help turnaround the juggernaut that is D&T.

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What is Design Volition? Implications for Technology Education

Jonas Hallström, Linköping University, jonas.hallstrom@liu.se
Piet Ankiewicz, University of Johannesburg, pieta@uj.ac.za

ABSTRACT

Design is a central aspect of technology education and has a prominent position in curricula all over the world, not only in subjects named Design and Technology (and similar) but also in most other technology and engineering subjects, or disciplines. In philosophy, it has been asserted that design *volition* (axiology) has a strong relationship with and in many ways forms the basis of design as a methodological stance. In this paper, therefore, we investigate the affordances of volition/axiology as an integral philosophical component of technology education, specifically in relation to design methodology. The primary philosophical frameworks used as the foundation for this philosophical analysis are the ones presented by Carl Mitcham in his *Thinking through Technology* (1994) and Andrew Feenberg's critical theory of technology. We perform a narrative review of relevant literature. Based on this review, we attempt a clearer definition of the lucid concept of volition/axiology in the literature, as well as explicate relationships and influences between axiology and methodology in which we also review design as societal phenomenon, strong and weak intentionality, determinism, etc. In conclusion, implications for technology education are drawn.

Keywords: Design, Volition, Axiology, Technology Education, Philosophy of Technology

1. INTRODUCTION

Design is a central aspect of technology education and has a prominent position in curricula all over the world, not only in subjects named Design and Technology (and similar) but also in most other technology and engineering subjects, or disciplines. Design lends itself particularly well to philosophical analysis because it is not only a making activity but also a pattern of planning and thinking, described succinctly by Mitcham (2020): "Design […] constitutes a distinctive way of turning making into thinking, engendering not only a special kind of making but also a unique way of thinking" (pp. 78–79). In philosophy, it has been asserted that design *volition* (in philosophy: axiology) has a strong relationship with and forms the basis of design as a methodological stance (Mitcham, 1994; Svenningsson et al., 2022). In this paper, therefore, we investigate the affordances of volition/axiology as an integral philosophical component of technology education, specifically in relation to design methodology. The primary philosophical frameworks used as the foundation for this philosophical analysis are the ones presented by Carl Mitcham in his book *Thinking through Technology* (1994), in which he expounds on a four-dimensional conception of technology as volition, knowledge, activity, and object, and Andrew Feenberg's critical theory of technology.

The selection of literature was carried out in line with criteria for *narrative reviews*, the object of which is to identify central literature for the topic at hand in relevant databases (e.g. ERIC, Google Scholar, Unisearch) without following a pre-determined protocol (Demiris et al., 2019). Furthermore, we included pertinent literature that was found in reference lists in previously known philosophical and technology educational literature, or the literature found through the searches (cf., Grant & Booth, 2009). The methodology for analysis in this conceptual paper subsequently consisted of philosophical analysis of said selection of literature. The degree of stringency of the philosophical argumentation then ultimately decides the relevance of the review and the analysis (Dusek, 2006; Hospers, 1997).

29. VOLITION AS PRESENTED BY MITCHAM (1994)

Volition, or in philosophical terms axiology, is an ill-defined concept which has not gained so much attention in philosophy as, for example, epistemology, ontology, and metaphysics. Volition basically means the ability or power to decide that you want to do something, for example, solve a problem, and then act upon it and take relevant action. In this context it means the will to do or achieve something with the help of technology. In the philosophical literature, however, volition can mean many things and Mitcham (1994) lists a number of these. Technology as volition could thus be the *will* to, through technology:

- survive or satisfy basic biological needs,
- pursue control or power,
- achieve freedom,
- obtain efficiency,
- be entrepreneurial,
- live and thrive,
- perform charity, temperance, altruism,
- exercise free will and creativity,
- create a vision of ourselves as humans, and
- achieve self-determination (pp. 247–250).

Thus, the human will to technology is both an individual act and a social/societal act, which reflect cultural and societal values. Overall, this means that technology is context dependent and value-laden, and this calls for various ethical analyses of technology (Ankiewicz, 2019; Feng & Feenberg, 2009; Keirl, 2018).

It is here that even the failure to will – incontinence – is important ethically because it may be difficult to translate knowledge into action, and sometimes we know what is right to do but we do not act accordingly. The failure of the will to do what is known to be good could potentially be "solved" by better information and communication, technological fixes, political decisions, legislation, etc. However, Mitcham asserts that all the way from St. Augustine to modernity, free will has been seen as superior to knowledge, understanding, and reason, which poses challenges when analysing and promoting certain technological solutions, or, conversely, when proposing that humanity must abstain from employing certain technological solutions. This makes technological ethics all the more important (1994, pp. 258–266).

A complication in any discussion of technology, ethics and free will is that it concerns the question of the moral “agency” also of technical artefacts and systems (Kroes & Verbeek, 2014), and thus also issues of technological autonomy, determinism and other related concepts (Hallström, 2022). Mitcham (1994) here bases his discourse on a Heideggerian argument, that understanding technology is essentially a practical activity and that technology in its essence is deeply related to volition; practical knowledge – procedural knowledge in making new technology – is therefore the most fundamental form of human knowledge, and it is closely connected with technological activity and volition. For Heidegger, in Mitcham’s interpretation, we can both use technology and be free of it at the same time, thus solving the dilemma of technological determinism and autonomous technology, but it requires both the will to will, and the will not to will, to say both yes and no to technology depending on the situation (1994, pp. 254–258). This latter Heideggerian stance may seem obscure, but it could be translated into the relationships – and tensions – between axiology and methodology in technological design.

30. DESIGN VOLITION: RELATIONSHIPS BETWEEN AXIOLOGY AND METHODOLOGY

The above discussion thus implicates a whole plethora of issues surrounding the human will to technology (and not to will), which may affect technological design in general and designing as a methodology in particular. There are important connections between axiology and methodology that need to be explored, that is, the significance of different axiological aspects of technological design and problem solving for such activities. We will here focus particularly on two of these issues: 1. Questions of how values affect designing and the designer, and 2. To what extent the will or intentionality of said designer can be considered to be decisive in designing, in comparison with values and other societal factors. Issues of determinism will be pertinent in both these problematics.

30.1 Values and design

We have mentioned above that technology is about control and that it is value laden, which aligns with Feenberg’s critical theory of technology as one of the prevailing views in the field of philosophy of technology (Achterhuis, 2001; Ankiewicz, 2019). Feenberg (2006, 2009b) contrasts the impact of critical theory of technology with the impact of determinism, instrumentalism and substantivism as the dominant views in the field of technology. He represents the relation between critical theory of technology and these other views in a table or matrix (refer to Table 1) with two axes – a vertical axis (the left column) representing the relation of technology to values, and a horizontal axis (the top row) representing the relation of technology to control or agency (Feenberg, 2006, 2009a, 2009b).

Table 1. The relation between critical theory of technology and other views (Feenberg, 2006, 2009a, 2009b)

Technology is	Autonomous	Humanly controlled
Neutral (complete separation of means and ends)	Determinism (e.g. modernisation theory)	Instrumentalism (liberal faith in progress)
Value-laden (means form a way of life that includes ends)	Substantivism (means and ends linked in systems)	Critical theory (choice of alternative means-ends systems)

Table 1 indicates that critical theory of technology shares traits with both instrumentalism and substantivism. Like instrumentalism, critical theory asserts that technology is in some sense controllable, but it also agrees with substantivism that technology is value-laden. This appears to be a precarious position since, in the substantivist view, the values embodied in technology such as efficiency and domination are precisely what cannot be controlled (cf., Ellul, 1964). Critical theory is sceptical about the capacity of human beings to get technological civilisation under reasonable control. It can, however, be reasonably controlled by being submitted to a more democratic process of design and development, also referred to as democratic intervention (Feenberg, 2006, 2009b). In this sense, critical theory of technology in Feenberg's version has developed into a critical, yet rather optimistic, view of design and technology development, provided democratic conditions prevail (Achterhuis, 2001; Ankiewicz, 2019; Hallström, 2022).

Critical theory thus develops Mitcham's (1994) conception of volition and holds that the values embodied in technology, referred to as technical codes, are socially specific and not adequately represented by such abstractions as efficiency or control evident in the dominant rationality. Technology can frame not just one way of life but many different possible ways of life or alternative rationalities, each of which leads to a different choice of designs and a different range of technological mediation (Feenberg, 2009b). On the one hand values are realised in designs and, on the other hand, design impacts on values (Feenberg, 2009a; Feng & Feenberg, 2009).

Consequently, current technical methods or standards were once broadly formulated as values and have at some time in the past been transformed into the technical codes or social standards reflecting specific social requirements that have shaped design but are taken for granted today. In sociological terms technical codes consequently are values (Riggs & Conway, 1991) and reflect what Feenberg calls secondary instrumentalizations, such as ethical and aesthetic mediations. Secondary instrumentalization involves the power relations or socio-cultural conditions that specify definite designs (Feenberg, 2005, 2009a; Feng & Feenberg, 2009). In critical theory of technology, a technical code directs the selection of a "best" design from a number of design possibilities. Technical codes are at times explicitly formulated as design requirements or policies but are often implicit in culture, training and education and need to be extracted from their context by means of sociological analysis. In either case, the designer should ideally formulate the technical code as a norm directing design (Feenberg 2005, 2009a; Feng & Feenberg, 2009).

30.2 Intentionality and design

If technical codes can be both explicit and implicit, the intentionality of the designer becomes a central concern in design from an axiological point of view. Feng and Feenberg (2009) present three different positions on design volition: 1. Designers as powerful, with a strong intentionality, 2. Designers as constrained, with a weak intentionality, and 3. Designers as embedded in society at large and thus with questioned intentionality. Although the critical theory standpoint leans toward the third of these positions on design volition, Feng and Feenberg still conclude that reality may include all three of them: "The intervention of non-technical influences on design takes the form of external pressures but it is also internal to the technical sphere itself. What appears technically rational to the designer is a function of many things, including her training and the codified outcomes of technological choices made in the past under various social influences. In other words, even when engaging in 'purely technical' activities, designers are guided by rules that are culturally specific and value-laden" (2009, p. 110).

Design is therefore a societal activity implicitly or explicitly codified by historical choices, at the same time as it is also directed toward the future by being about problem-solving, creativity and innovation (Feenberg 2017). Therefore, both the history and the current state of the art in technology set limits for what can be achieved in design, so there is also a deterministic potential that may lead to unintended consequences of any new technology (Van der Vleuten, Oldenziel, & Davids, 2017; Winner, 1986). This could be both technological determinism and social determinism, depending on what factors dominate (Hallström, 2022). However, Feen and Feenberg (2009) argue that technology is underdetermined, which means that values always determine the design and development of technology through the technical codes. The important thing is for designers and society at large to acknowledge this fact and make sure that technology is developed with good, democratic, and liberating values, as opposed to controlling, oppressive, and undemocratic ones: "Critical theory of technology draws attention to these background assumptions and asks that the researcher take these seriously. Our hope is that by *questioning* technology vigorously we can help open a space for *designing* technology differently" (p. 117).

31. DISCUSSION AND IMPLICATIONS FOR TECHNOLOGY EDUCATION

The philosophical literature on axiology/volition was and is scarce, but Mitcham (1994) goes some way in explicating more clearly what it is and the role it plays in technology development in relation to primarily epistemology/knowledge and methodology/activity. He pinpoints several definitions of volition such as the will to satisfy needs, control, live and thrive, and connects it with power, freedom, efficiency, etc. (pp. 247–250). In recent years, Feenberg has also developed axiological analyses of design in relation to societal and cultural values, as embodied in technical codes. In both Mitcham's and Feenberg's work issues of intentionality, agency, autonomy, values/ethics, determinism, and consequences are dealt with in intricate but convincing philosophical analyses (Mitcham, 1994, 2020; Feenberg, 2005, 2009a, b, 2017). In relation to the aim of this study, both Mitcham and Feenberg thus investigate affordances of volition/axiology for technological design and show that design methodology cannot be construed as a purely "technical" activity but axiological aspects of designers' and society's pursuits influence designing in decisive ways. The relationships between axiology and methodology therefore appear both in the various ways in which the intentionality of the designer takes form (strong/weak/society), and in the ways values (technical codes) are implicitly or explicitly assigned to or embedded in designs. This paper thus contributes to the field of design, technology, and engineering education by explaining *why* values are important to consider in design, and *why* one cannot assume that a designer can just do what she or he thinks is suitable but that their intentionality/volition might be restricted by various cultural factors.

The philosophical analyses of this paper could, in turn, help develop the way we conceive of, analyse, and teach design in technology education. Feenberg's critical theory of technology and Mitcham's conception of volition support the inclusion of design volition in technology education. A technology education founded on design volition does not reduce technology education to technical education, which is based on determinism and instrumentalism that view technology as value neutral. It will also not fall short of a critical assessment – unlike substantivism – that might explain, for instance, why some technologies, but not others, are developed in a society (Conway and Riggs 1994; Hansen 1997; Martin 2002; Stables 2017). As critical theory of technology aims at uncovering the technical codes – which are biased by the values imposed by the strong intentionality of expert designers – and to change them to the advantage of modern democratic societies (Feenberg 2009a), technology teachers and students need to be explicit about the values involved at all levels of technology and to clarify, justify and debate their choices (Conway and Riggs 1994; McLaren 1997; Pavlova 2005). Students should be given the opportunity to reflect on their explorations of a value-based appraisal of technology in society by identifying the technical codes and allowing their reflections to influence their own approach (or technical code) to design (McLaren 1997). Students should be accorded opportunities to not only act as expert designers, following a strong intentionality approach (Dakers 2005), but also to follow a weak intentionality approach during negotiations with lay designers (cf. Ankiewicz, 2019).

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Authenticity in Integrated STEM Education – Boon or Fantasy? Observing Upper Secondary Technology Classroom Practice

Jonas Hallström, Linköping University, Sweden, jonas.hallstrom@liu.se
Charlotta Nordlöf, Linköping University, charlotta.nordlof@liu.se
Per Norström, KTH Royal Institute of Technology, perno@kth.se
Konrad J. Schönborn, Linköping University, konrad.schonborn@liu.se

ABSTRACT

Engineering design and technological modelling have been argued as valid premises from which to increase authenticity, relevance and create bridges between the STEM disciplines while maintaining subject integrity. Previous research indicates that projects which emulate how engineers work has the potential of both integrating STEM disciplines and being authentic. At the same time, earlier research also cautions that few integrated STEM projects consider students' interests and their everyday contexts. The aim of this study is to investigate the implementation of an integrated STEM project in the Technology Programme at a Swedish upper secondary school. The studied STEM project involves students' designs for improving their physical school environment in terms of well-being, feasibility, and sustainability. Data collection consisted of participatory observations, as well as teacher and student interviews. The results are presented in terms of three themes, namely (1) cooperation and real-life application are fundamental for authentic learning; (2) using models and modelling for communicating design ideas are central to authentic technology and engineering; and (3) integration of STEM content and methods do not draw on all four disciplines. It is concluded that there might be easily accessible pathways to promote integrated STEM and authenticity, such as utilizing the school environment as a starting point. However, formally implementing authentic practices remain a challenge even though a majority of teachers are enthusiastic about real-world relevance in design projects. Integrated STEM in the design project mostly included technology and engineering content, and aspects of science and mathematics albeit to a lower degree, which made simultaneous integration of all STEM disciplines a challenging task.

Keywords: Technology Education, Engineering Design, Integrated STEM Education, Upper Secondary School, Authentic Learning.

1. INTRODUCTION

In recent years, engineering design and technological modelling have been argued as valid premises from which to increase authenticity, relevance and create bridges between the STEM disciplines while maintaining the integrity of each subject. Recent conceptual (Hallström & Ankiewicz, 2023) and empirical (English & King, 2015; Lin et al., 2021) studies indicate that projects which emulate how engineers work have the potential of both integrating STEM disciplines and being authentic. However, scholars such as McLure et al. (2022) caution that few integrated STEM projects consider the students' interests and their everyday contexts, which presents a challenge if integrated STEM education is intended to promote authenticity. In addition, authenticity is a contested phenomenon, not least when it comes to discerning *for whom* something should be deemed authentic (e.g., Anker-Hansen & Andrée, 2019).

The aim of this study is to investigate the actual implementation of an integrated STEM project in the Technology Programme at a Swedish upper secondary school. The studied STEM project involves students' designs for improving their school environment in terms of well-being, feasibility, and sustainability. We investigated the implementation of the project as well as how teachers perceived it.

33. THEORETICAL BACKGROUND

Authenticity in education is a popular, yet at the same time a very contested notion (Schriebl et al., 2022; Watson, 2008), as far as the term often induces the question, "authentic for whom?". Typical definitions of authenticity include that by Rule (2006) who describes authenticity as "learning in contexts that promote real-life applications of knowledge" (p. 1). Furthermore, Shaffer and Resnick (1999) have identified four inter-related types of authentic learning, namely: (i) learning that is personally meaningful, (ii) learning that relates to the real world outside of school, (iii) learning that relates to a particular discipline, and (iv) learning where assessment reflects the learning process. In focusing on *learning*, one centres the "for whom" question on the student recipient (Anker-Hansen & Andreé, 2019). Doing so also caters for students' own perceptions of authenticity, which in turn, might engage a further motivational component in their learning (Behizadeh & Engelhard, 2014; McLure et al., 2022). Since promoting authentic learning is regularly mooted as conducive to "real" settings and practice, technological praxis (e.g., technology and engineering) serves as a valid context from which to generate authentic learning activities (Turnbull, 2002). Hence, integrating authentic learning into upper secondary school technology programmes could serve as a meaningful point of departure (e.g., Svärd et al., 2022).

Contemporary literature views authentic learning as highly connected to STEM education and modelling. Authenticity in an engineering context is often embodied in design projects, which according to Pleasants (2020) could be based either on solving "pure STEM problems" or "STEM-relevant problems". According to Davies and Gilbert (2003), modelling activities spawn natural connections between, for example, the STEM disciplines, science, and design and technology due to overlapping modelling practices. Such a notion could even be extended to mathematics and engineering and thereby serve to forge further authentic connections.

In this study, we loosely adopt a definition of authenticity that emphasises students' participation in practices and activities of professional scientists, technologists, engineers or mathematicians, or activities appropriate for, or corresponding closely to such professional practices for solving real-world problems. Thus, authenticity comes in various forms and degrees that can be combined in a multitude of ways. Employing methods and instruments used in professional activities is one form of authenticity, whilst solving problems like those solved by professionals is another. Authenticity could also be forward-looking in terms of the design of products that could potentially be marketed, while authenticity could also lie in the methods of problem solving (see Murphy et al., 2006).

34. METHODS

Data collection was conducted at an upper secondary school in Sweden. The educational programmes that the school offers are included in the upper secondary curriculum, and the specific selection at this school is dominated by technology and introductory engineering programmes which collaborate closely with local industries.

An integrated STEM project involving the design of an indoor or outdoor environment was presented to 24 groups and 180 students altogether, within the programmes Technology; Health and Social Care; Electricity and Energy; and Industrial Technology. Three of the four authors collected data, during the full three weeks (18 April until 5 May, 2023) that the project lasted. Based on student consent, it was possible to collect data from 10 specific groups. In each of these, at least one student was enrolled in the Health and Social Care programme while the remainder were Technology programme students. The groups consisted of between 4 and 7 students. The project represented an integrated STEM (iSTEM) engineering design project that dealt with the design of an indoor or outdoor environment and artefacts that should promote good health. For the Technology programme students, the project took place during the final weeks of "Technology 1", an introductory technology course where the learning objectives include technical drawing, history of technology, and project management.

We carried out participant observation of the students and their solutions and designs as they engaged in the project, and solving the problem related to design of an environment that promoted healthy living. The school had worked with integrated STEM projects previously, but this one was larger and more organised. Furthermore, we observed the teachers and how they interacted with the students. We also interviewed teachers and students (see table 1). We collected the students' written documentation in the form of a logbook. The observation protocol was inductive, in the sense that we studied subject content, working methods, work environment, as well as degree of integration, model use, and authenticity. We asked related questions to both students and teachers, to garner their views on the degree of authenticity of the project, and related views of how the project transpired. The interviews were audio-recorded, and observations documented through field notes. All data were collected in Swedish and translated into English. Data collection and data storage were carried out according to Swedish and European law (General Data Protection Regulation, GDPR), and informed by the ethical research guidelines of All European Academies (ALLEA, 2017).

Table 1
Project Activities and Data Collection Timeline Adopted in the Study

	Activities	**Data collection type**
1st week	Introduction Solution suggestions Idea pitch	Teacher interviews (before commencing) Observations
2nd week	Physical modelling	Observations Teacher interview
3rd week	Preparation for final presentation Final presentation	Observations Student interviews
4th week	Reporting	Teacher interviews (after completion)

Inductive qualitative content analysis was performed on the data (Elo & Kyngäs, 2008). All authors participated in the analytical process. The analysis was informed by implicit and explicit references to aspects of authenticity and modelling, namely in activities and work organisation, in equipment, in problems, or contextual factors such as money, time, standards and security regulations.

35. RESULTS

Based on the observations and interviews with teachers and students that participated in the design project, the analysis yielded three themes:

35.1 Cooperation and real-life application are fundamental for authentic learning.

The nature of authenticity in the design project, as perceived by teachers and students, is that it is the design/product that is to be authentic and useful. As such, the concept of authenticity is therefore forward looking and future oriented, and the product should therefore have the potential to be produced or to solve a present or future problem. In the introduction of this project, the teachers pointed out the opportunity to have one or more of the students' ideas implemented in real life at their school.

There is also authenticity in how the assignment was presented and in the working methods. The work was performed in smaller groups where students from different educational programmes were mixed. As represented in the quote below, from the teachers' perspective, this was one way to make the project authentic:

> You can really see it as a problem-solving process, a structured method for solving problems. For the Technology programme it could be roughly like how an engineer works, but for the others it can be problem solving in their own areas, organisational development in industry and similar (Interview, Technology teacher 1, 18 April 2023).

When introducing the task, another teacher encouraged the students to practice cooperating together and told them that "this is what it looks like in real life" (Field notes, English teacher, 18

April 2023). Also, the same teacher emphasised that in cooperating "everyone does not do the same thing" (Field notes, English teacher, 18 April 2023), it is about finding your strengths and contributing to the task. The connection to work life and mixing competencies is one of the main pillars of the project that contributes to authenticity (Nordlöf et al., 2022), which is something that the teachers maintained in the interviews, revealed in utterances such as:

> Different competences and knowledge are at least as important for carrying out the project successfully, for quality, and for efficiency – just as it functions in working life" (Interview, Technology teacher 2, 18 April 2023).

During the first week of the project, a presentation was given to introduce students to the design process. The teacher had experience in working as an engineer, which was explicit in the teacher's presentation. For example, she referred to companies familiar to the students and talked about the design process in terms of what the companies do, as per comments such as "they work with this process every day."

An example of a lack of authenticity was described by one student. He felt that the project was not authentic since they had no budget or economic framework to relate to, which would have been normal in a real-life project.

35.2 Using models and modelling for communicating design ideas are central to authentic technology and engineering.

The teachers introduced the project by encouraging students to build their own cardboard models of their school environment designs. Such a model should be a means of displaying and explaining their idea to others, as part of their presentation of the product. For example, as one teacher said, "you do not bring a whole car to a meeting, but a model of a car could be presented" (Field notes, Technology teacher 1, 24 April 2023). A model could also be a way of showing the functions of a product, for example, in a physical model of a building (Norström & Hallström, 2023).

Many examples of modelling emerged from the observed activities. For example, the students generated pencil-and-paper sketches and simple CAD models to explain their ideas within the group. They also used photos, Google Maps, and other applications to convey ideas. One group had even obtained original blueprints of the school building to obtain exact measurements.

The modelling performed in the design project was mostly served to communicate design ideas within the project group, and to the teachers and members of the jury in the final innovation competition. Thus, while modelling is not performed to test design ideas, it plays a vital role in communication. Thus, while the models and modelling are authentic, there are essential elements of real modelling such as industrial enterprises that are lacking.

35.3 Integration of STEM content and methods do not draw on all four disciplines.

Implementing the design project as an example of integrated STEM functioned in the sense that the activities included technology and engineering problem solving together with some mathematics, albeit at the lower-secondary level in the latter case. For example, mathematics was applied in measuring and converting scales and when building physical models. Students also performed simple geometrical calculations in relation to physical modelling and deducing scale. In Sweden, such calculations comprise lower-secondary mathematics education, and the mathematics integrated in the activities was not equivalent to the upper-secondary education Technology programme. Technology teacher 2 commented this in the following way:

> Well, about that, it's not really upper-secondary maths. […] As it was, the maths wasn't planned but was more brought in as an aid. […] Because the task in itself didn't require maths at a high level, but that doesn't mean that it wouldn't be possible to implement at a higher level (Interview, Technology teacher 2, 16 May 2023).

The same situation also arose when it came to integrating science education in the project. There was indeed content and methods that could be construed as science-related, in relation to health issues and well-being such as encouraging a healthy lifestyle, which are components of biology education. However, the students had already studied these perspectives at lower-secondary level, so these were not emphasised, or seen as explicit biological learning goals. Instead, science integration was related to the fact that students from the Health and Social Care programme participated in each group.

While the depth of exposed technology and engineering knowledge was not extensive, it is important to note that the participants were first year upper secondary students. Nevertheless, there was a great deal of focus on engineering working methods, such as project work, teamwork, and cooperation, which meant that technology and engineering content was still foregrounded (cf., Nordlöf et al., 2022).

36. CONCLUSIONS

At this point in the research programme, the overall conclusion from this project is that there might be easily accessible pathways to promote integrated STEM and authenticity, such as utilizing the school environment as a starting point. However, formally implementing authentic practices remain a challenge even though a majority of teachers are enthusiastic about real-world relevance in design projects. Integrated STEM in the design projects mostly included technology and engineering content, with some science and mathematics albeit at a lower level. The findings thus point to the difficulties involved in integrating all STEM disciplines simultaneously. Paradoxically, despite these observations, the Swedish curriculum encourages in-depth subject studies as well as interdisciplinary work. Frame factors also affect the possibility to work in a way that promotes the integration of STEM subjects, such as the structure of the schedule and how subjects and courses are executed. If increased STEM integration is sought, then introducing a curriculum that explicitly encourages subject integration would be beneficial.

Although the project did not expose extensive "depth" in knowledge, it did succeed in focusing on and unleashing cooperative and creative skills. The integrated subject knowledge was often at a lower level, as shown when mathematics was applied. If the purpose of integrated STEM is to also develop knowledge in separate disciplines such as mathematics or chemistry, the STEM project needs to be more closely related to contemporary upper secondary subject content, and the teachers need to plan problems with a clear subject focus.

The study highlights cooperation and teamwork as being key to achieving any true form of authentic learning – inferring that realising authenticity relies on cooperative dimensions. In turn, this also has implications for assessment. Much merit is to be found in “wonderful messy modelling” processes for communicating design ideas. Indeed, being part of a structured engineering design process is a learning objective in itself. Although challenging to achieve, the process also provides a framework for learning about technologies related to ergonomics, architecture, and construction. It is apparent that most groups learned about the process, but to what extent requires further exploration.

Finally, in reference to Shaffer and Resnick’s (1999) definition (apart from considering assessment), the project can still be deemed an authentic enterprise. The project can also be construed as personally meaningful to the students since it relates to real world problems within their own direct school environment (McLure at al., 2021; Shaffer & Resnick, 1999). When it comes to STEM, the studied project deals with both a narrower as well as broader set of problems than what Pleasants (2020) terms “pure STEM problems”. Focusing on solving technological and engineering problems with only a hint of mathematical and science problems might account it as narrower. But integrating economic and health problems in relation to Pleasants’ (2020) “STEM-relevant problems” also render the project broader.

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Teacher Training in Robotics: Evaluating the Implementation of Robotics and Teacher's Motivation and Self-efficacy Towards Robotics.

Dani Hamade, Universität Oldenburg, dani.hamade@uni-oldenburg.de
Jan Landherr, Universität Oldenburg, jan.landherr@uni-oldenburg.de
Carl von Ossietzky, Universität Oldenburg

ABSTRACT

The competent, critical, cooperative, and creative use of digital technologies has become a fundamental requirement for participation in society and professional life. Human-robot collaboration, which is increasingly common in industry, and networked production through the Internet of Things are prime examples of this. Teachers therefore need to be prepared for the challenges in times of digital transformation in order to prepare students for the increasingly digitalised labour market of today and tomorrow. As part of the so-called master plan for digitization, the project "Robonatives" is equipping technology labs at 65 schools. In order to ensure a structured implementation in line with the project's objectives, the University of Oldenburg, among others, is supporting these schools in the development of curriculum for long-term integration into the schools' own curriculum. Teachers are provided with advanced training courses addressing the use of robots, occupational safety, and ethical and social issues, as well as the design of learning situations. The aim is to establish the topic in schools in the long-term, beyond the project's duration (24 months). In line with this, the article presents and evaluates a study on how robotics is embedded in the lessons of the project schools. A further aim of the evaluation is to measure the teachers' motivation and self-efficacy to teach robotics, in order to evaluate the training concept and to identify further needs.

Keywords: Robotics, training courses, teacher education, motivation and self-efficacy

1. INTRODUCTION

The influence and proliferation of robots in various sectors, both private and commercial, continues to grow. As the world increasingly moves towards Industry 4.0, an era defined by intelligent automation and digital connectivity, the impact of robotics on the economy and everyday life is growing. According to Statista (2022), the number of robotic systems in industrial production increased from around 121,000 in 2010 to 517,000 in 2021. Given this upward trend, it is clear that understanding and effectively interacting with robots will become a necessary skill for future generations.

In popular media landscapes such as films, video games, and literature, robots are often portrayed as intelligent beings possessing superior strength and speed, potentially posing a threat to humanity. In contrast, robots in everyday life, such as vacuum cleaners or lawn-mowing robots, seem more inclined towards menial tasks. This dichotomy raises a crucial question: How can we bridge the gap between the capabilities and applications of real robots and their portrayal in the media?

Recognizing the importance of integrating robotics into education, the state of Lower Saxony has launched the "Robonatives" project as part of its Digitalisation Master Plan (. This project aims to equip general education schools with technology labs and establish innovation and future centres at vocational schools, with a focus on robotics and care. The ultimate goal of this project is to integrate robotics into school curriculum in the long term, and to foster a generation of people who are comfortable with and competent in interacting with robots (Niedersächsisches Ministerium für Wirtschaft, Arbeit, Verkehr und Digitalisierung, 2018, p. 77). The title "Robonatives" itself draws an analogy with concept of "digital natives", describing people that grew up with robotics and are familiar with their usage.

1.1 Educational concept

The project is supported by three University Robotics Competence Centres. Their main task is to support schools in developing instructional arrangements for the sustainable integration of robotics. These centres offered eight-hour professional development courses for teachers, focusing on various aspects: the use of robots, safety precautions, ethical and social issues, as well as the design of learning scenarios. The primary aim of the project is to promote a STEM (Science, Technology, Engineering and Mathematics) orientation among learners and to prepare them for the technology-driven world of Industry 4.0.

Table 10.
Overview of the training contents

Course	Main content	Course	Main content
1	Commissioning of the robots, Teach&Playback, Safety instructions	6	Industry 4.0 and connected production using I/O ports and phototransistors
2	Introduction to visual programming with Blockly	7	Internet of Things via MQTT
3	Programming of end effectors and actuators	8	Use of a 3D printing module
4	Programming a linear axis	9	Programming the vision kit for object detection
5	Programming with Python	10	Programming the AI Kit

The school infrastructure is being equipped in such a way that teachers have the opportunity to integrate robotics into the classroom in a practical manner.

To be able to impart the necessary digital skills and knowledge in the field of robotics to their students, teachers themselves need to have the appropriate competencies. This includes not only technical skills but also pedagogical and pedagogical content knowledge to ensure the transfer of this knowledge.

For this reason, special training courses were developed and delivered at the participating universities during the course of the project. Teachers from the participating schools attended these professional development courses to prepare for their new tasks.

1.2 Motivation and teachers' self-efficacy in relation to robotics as part of professional action competence

"There is a broad consensus in the didactic literature that knowledge and skills [...] are central components of teachers' professional competence" (Kunter et al., 2011, p. 33; translation by the authors). This includes content and pedagogical content knowledge. Following this thought, a special emphasis was placed on the imparting of basic skills and knowledge in robotics during the training courses. This is intended to enable teachers to provide independent and well-founded instruction in this area.

However, knowledge and skills are only facets of the more comprehensive professional action competence of teachers. Other key factors include beliefs in self-efficacy and self-concepts of abilities, which have a strong influence on how teachers plan and carry out their instruction. In particular, these factors manifest themselves in the motivational orientation of teachers: Teachers with a strongly developed sense of self-efficacy often show more enthusiasm and professional commitment. This can, for example, have a positive effect on student motivation and consequently on student performance. Furthermore, additional motivational aspects, such as subject-specific interest or the enjoyment of engaging with the subject matter, can play a crucial role in the self-concept of teachers' abilities and therefor for the quality of their lessons: “Teachers who practice their profession with enthusiasm fulfil the task of teaching with higher quality and also achieve more favourable results with their students” (Kunter 2011, p. 269, translation by the authors).

Based on these considerations, the authors of this paper conducted a study in which they analysed, among other things, the motivation and self-concept of abilities of the participating teachers using a questionnaire. The aim was to identify in which thematic areas the teachers see further need for professional development, what their motivation looks like to teach certain subject areas, and how they assess their own abilities regarding instructional delivery and planning.

2 METHODOLOGY

2.1 Research questions

During the course of the project, an extensive survey was conducted with the teachers directly involved in the project. A key objective of this survey was to gain a detailed understanding of the current state of robotics integration in the funded schools.

One aspect of interest is to get an overview of robotics equipment in the schools and the extent to which it is being used in the classroom. In this context, it was important to find out where the teachers still see challenges in order to derive appropriate measures. The motivation and attitudes of the project teachers towards robotics were also investigated. These aspects are of considerable importance, as teachers' attitudes, which can also be seen as an aspect of professional competence, have a significant influence on the successful implementation of topics in the classroom. Another focus of the survey was on the project teachers' self-efficacy towards robotics.

Teachers' self-efficacy of their competencies and skills can also play a crucial role in their willingness to integrate robotics into the classroom. The results of this teacher survey provide valuable insights for the future design of training programmes and the further promotion of the integration of robotics in schools. By understanding teachers' usage behaviour, attitudes and self-efficacy, targeted interventions can be developed that are adapted to teachers' needs.

To address this, the following research questions were developed:

(i) To what degree were robotics curricula integrated into the funded schools?
(ii) What robotics equipment was available in schools?
(iii) What were the motivating factors behind teachers' efforts to teach robotics?
(iv) What attitudes did teachers have towards teaching robotics?
(v) What role does teacher self-efficacy play in their ability to teach robotics?

2.2 Data collection and instrumentation

For the investigation of the aforementioned aspects, a cross-sectional research design was used. For this purpose, a questionnaire was created and distributed to the participating project teachers. Furthermore, for reasons of research economy, it was decided to use a questionnaire in digital form, as there is a wide geographical spread between the participating project schools. Surveys on the use of robots in the classroom are hardly to be found in German-speaking countries. However, with regard to the use of digital technologies in general, there is a large pool of adaptable questionnaires available, which can be adapted in the sense of the research objectives presented here. For example, Du Bois (2005) investigated teachers use of computers in schools. In particular, the items related to the use of computers at school could be extracted and adapted to robotics. Another aim of the study is to examine aspects of teachers professionalisation. One facet that will be brought to the fore here is the motivation of the teachers with regard to the teaching of robotics and automation technology as well as their self-efficacy in this regard. For the survey of professional competence, a large number of studies are available, so that items could also be adapted here. For the attitude survey, the choice fell on the instrument developed by Reinke (2022) to assess the professional action competence of teachers and on components of the COACTIV ("**Co**gnitive **Activ**ation in the Classroom") studies (Kunter et al., 2011). The corresponding items were also adapted. In addition, items from Pfitzner-Eden, Thiel & Horsley (2014) that deal with the assessment of teachers' self-efficacy were used.

The resulting questionnaire consisted of four main sections. The first section collected basic demographic data (gender, classes and school type, for how long the teachers have been teaching and the subjects they teach), while the second section included items to assess usage behaviour and teaching experience in robotics (which robots they have, which programming language they use, contexts they teach robotics in, what they focus on while teaching robotics, usage of robots before and after the project and how they perceive student motivation). The third section focused on measuring the teachers' motivation towards robotics and their self-efficacy. The items in relation to the self-efficacy were designed to measure the teachers' basic perceptions of their ability to perform certain tasks in the context of robotics. The items were divided into three areas: system handling, teaching situations, and lesson planning. Finally, at the end of the questionnaire, participants had the opportunity to provide additional comments in an open-ended field.

A variety of question types were used, with the majority being closed-ended questions. In some cases, closed questions were accompanied by a text box where teachers could provide additional information. Thus, hybrid or semi-open questions were included alongside closed questions. There were also different scales used within the questionnaire. Nominal scales were used alongside ordinal scales to establish rankings (ordinal scales from 1= strongly agree/applies to 4 = strongly disagree/does not apply). The results were imported in the software SPSS-Statistics where methods of descriptive statistics were used to analyze the variables.

2.3 Sample

The data were collected from a total of 54 participating general education project schools, so the sample consists of teachers working in those schools. This resulted in a population of N=108 teachers who were being trained in robotics. In total 49 teachers of different schools ended the questionnaire with answering all questions. Incomplete questionnaires were not included in the data. There were 42 male and seven female secondary school teachers (teaching from class five to ten) among the respondents. The teachers have different teaching experience. Nine of the teachers are teaching since two to six years, 15 between six and 10 years and 25 more than 10 years.

Given the sample size, it should not be assumed that the results of this study can be fully generalized to the whole population. However, it can be said that the sample has a high degree of representativeness in terms of characteristics. This is reflected in the distribution of school forms and the geographical representation, as teachers from both urban and rural areas are represented in the project.

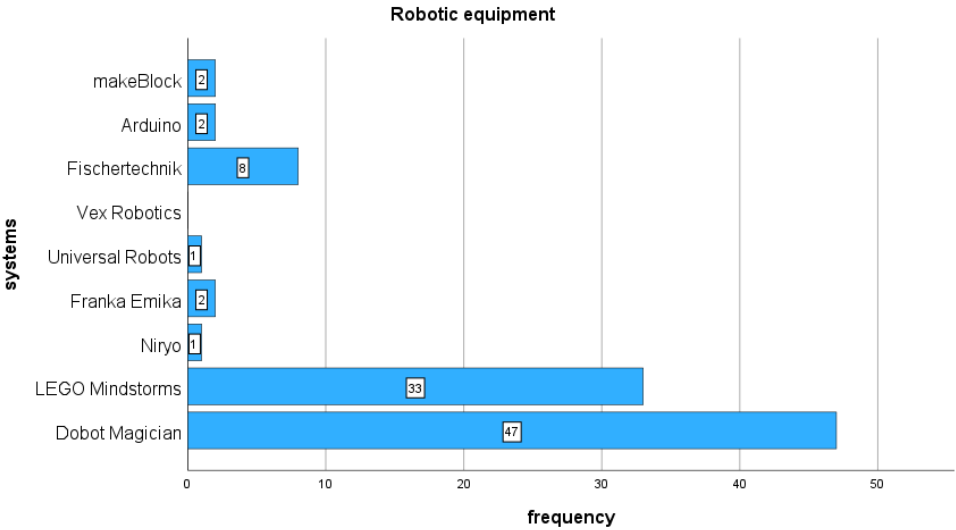
3 RESULTS

3.1 Usage of robots at schools

The items used to assess the implementation of robotics in education focus mainly on the equipment and its use, the forms of programming and the thematic contexts in which robotics is taught. First of all, an overview of the robotics technologies in the schools was to be obtained as part of the project.

In this regard, teachers were given predefined options to choose from for each school, as well as the opportunity to provide their own additions in an open-ended response field. The results indicate that the majority (47 out of 49 participating schools) possess the Dobot Magician. Following in second place is the LEGO Mindstorms system, with a total of 33 schools (see Figure 1).

Figure 23.
Robotic-Equipment in the participating schools.



The majority of teachers (N = 40) also report that they have been teaching robotics and using the acquired technologies on a regular basis since the beginning of the project. The results show that the proportion of robotics lessons has increased significantly as a result of the project. Many teachers who were not teaching robotics before have been doing so regularly since the project started (a total of 28 of the teachers said that they were already teaching robotics before the project started). Furthermore, 42 teachers indicated that robotics had become an integral part of the school's internal curriculum. Of these, 20 teachers also use the robots in interdisciplinary contexts. Additionally, 35 teachers mention that robotics extracurricular activities are offered outside of regular classes. The results also show that the introduction of robotics has led to a change in the school's attitude in terms of funding and physical reorganization (see Figures 2 and 3).

Figure 24.
Changes in subject rooms.

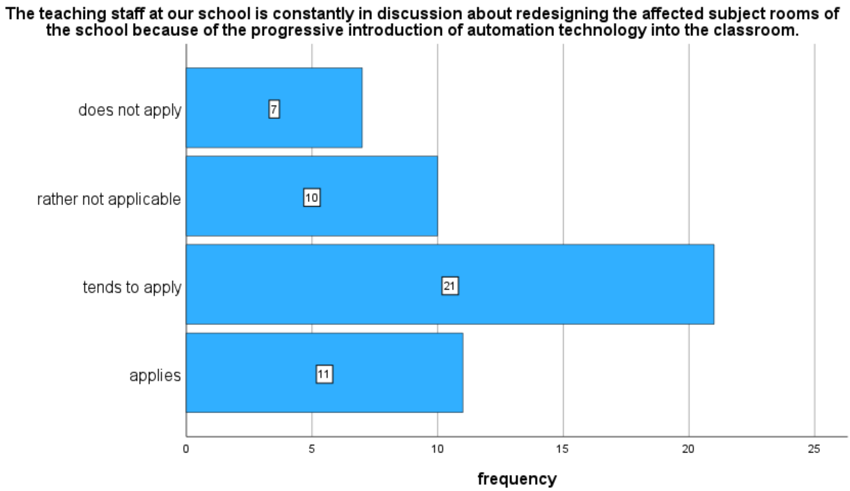
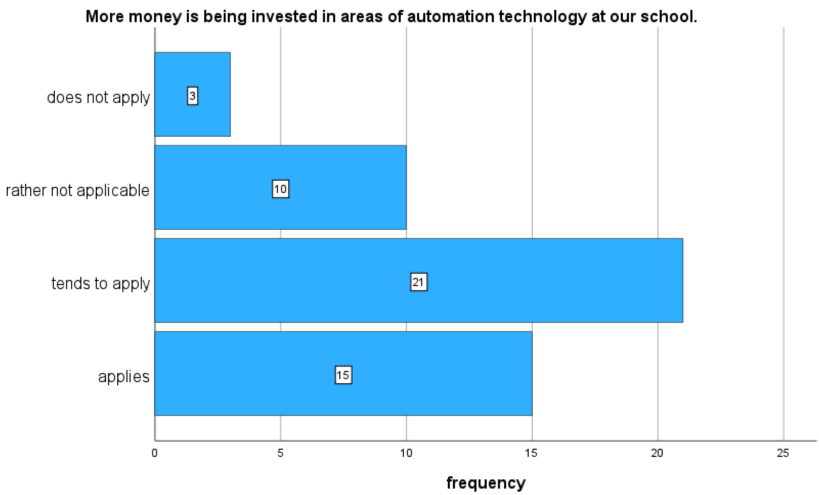


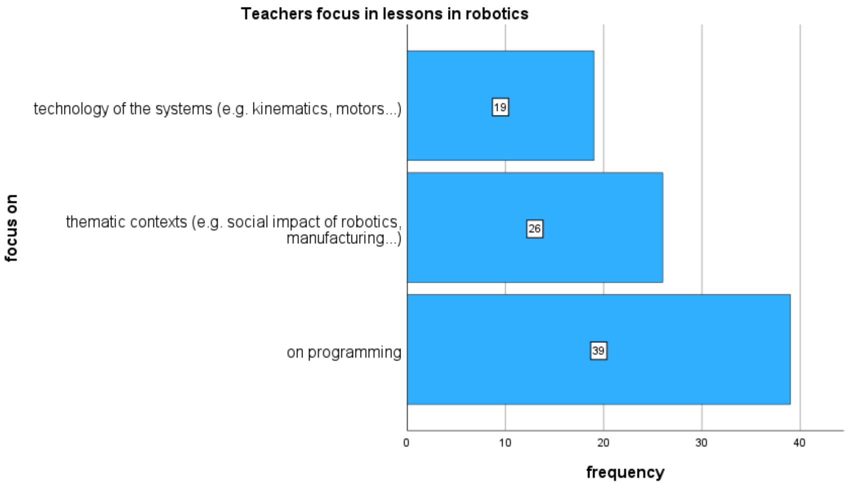
Figure 25: Money being invested in automation



The following are the findings on the implementation of robotics in the classroom. Firstly, it was investigated where teachers place their emphasis when implementing robotics in the classroom (see Figure 4).

The greatest emphasis is placed on robot programming. This is followed by thematic contexts, such as the societal impact of robotics or the industry. The least emphasis is placed on the technical aspects of the systems, such as kinematics (see Figure 4).

Figure 26: On what the teachers focus in lessons.



The type of programming used for the robots was also investigated (see Figure 5). Almost all teachers (N = 48) reported that they use block-based programming. The second most common approach is Teaching & Playback (N = 35), while text-based programming is the least used (N = 10). Teachers also indicated that text-based programming tends to overwhelm their students M = 1.92, SD = 0.64. In addition, many of the teachers indicated in the open responses that they still need further training in text-based programming of the robots and do not feel confident in using it.

In addition to programming, as mentioned above, teachers often place a strong emphasis on thematic contexts. Another item was used to investigate teachers preferred thematic contexts related to robotics (see Figure 6). It can be seen that the majority of teachers (N=48) favour the industry (manufacturing) as the preferred context.

Figure 27.
Type of programming languages used.

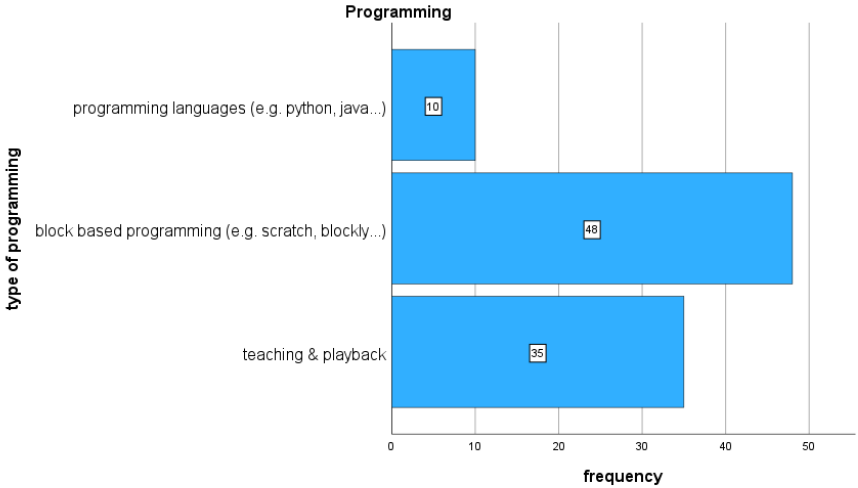
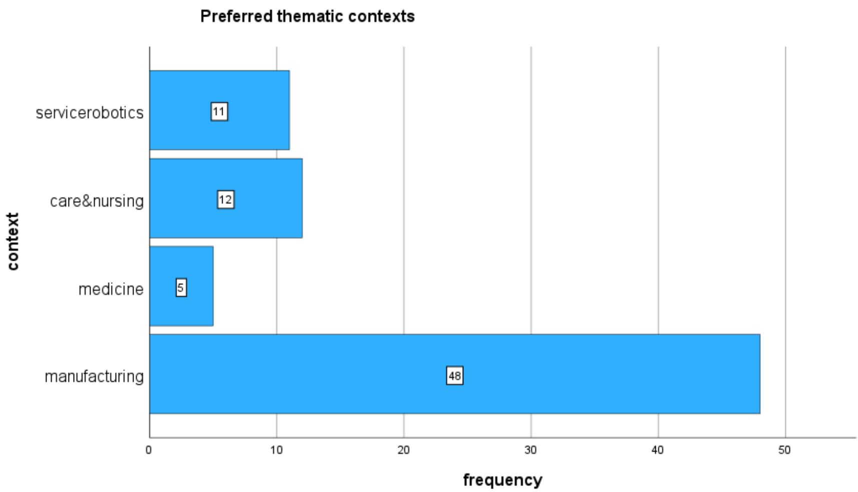


Figure 28.
Which thematic context teachers prefer in robotics.



Conclusively, an item was administered to assess the extent to which teachers perceive robotics to facilitate interest and access to technical concepts.

The items were grouped into a single construct and with *M*=1.54 and *SD* =0.45, the teachers agree that working with robots stimulates students' interest in technical subjects, facilitates their access to such concepts, and generates enthusiasm among the students (see Figure 7-9).

Figure 29.
Teachers' belief on interest encourage through robotics.

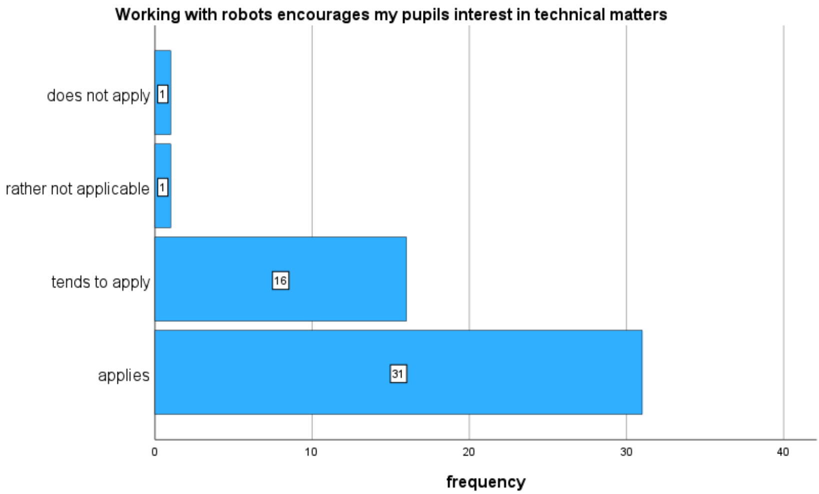


Figure 30.
Teachers' belief in access to technology through robotics.

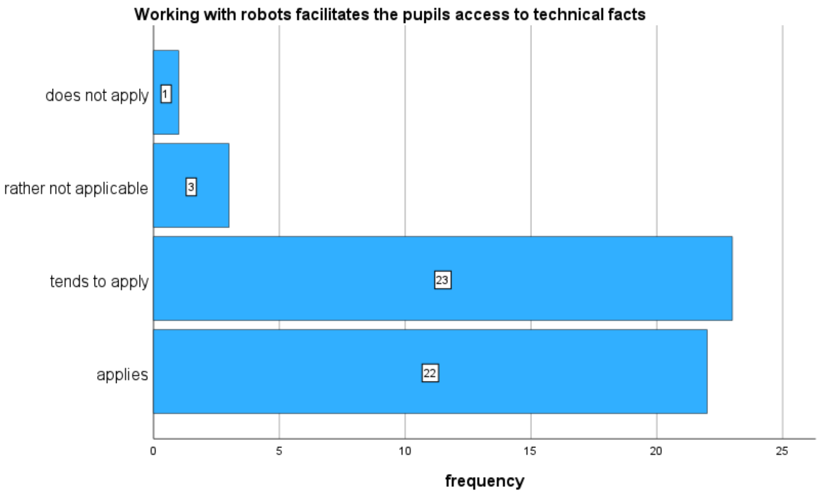
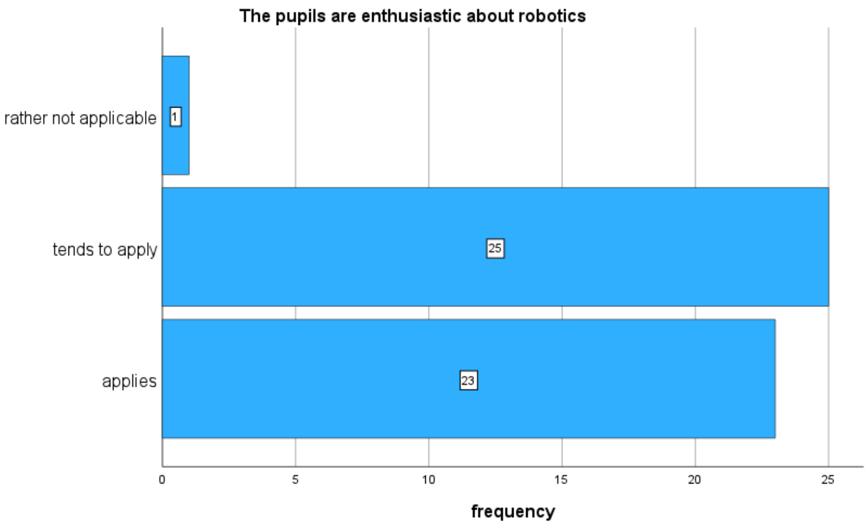


Figure 31.
How teachers perceive enthusiasm about robotics.



3.2 Teacher motivation and self-efficacy in robotics

The focus of this section is to present the results regarding the teachers' motivation towards robotics. Motivation was assessed using a series of ordinal scale items. The individual items relate to the interest in robotics, as well as an assessment of the importance of topics related to robotics and automation technology in general (see Table 2).

The mean values indicate an overall high level of motivation among the teachers in relation to robotics (aggregated mean *M=1,51 SD*=0,34). Most of the teachers are interested in robotics, enjoy teaching content that is related to robotics and think, that it is important to have robotics in classroom. But there are still problems influencing the teachers motivation. For example, one teacher stated in an open-ended field:

"There is simply not enough time in everyday life to deal intensively with the existing robots. The training courses are great, but the practical part in daily business is missing" (Translation by the authors).

This statement shows that it is of great importance to offer and expand such intensive and detailed training concepts as in this project. Providing teachers with the appropriate undisturbed space, time and support to engage with robotics (this certainly applies to other subject areas as well) can help to maintain motivation.

Table 11.
Motivation to teach robotics (1=strongly agree to 4=strongly disagree)

Item	M	SD
I find the topic of robotics interesting.	1.24	0.43
The use of robotics in the classroom is an important concern for me.	1.29	0.46
I enjoy teaching content related to robotics.	1.41	0.54
Teaching technological progress in automation technology in the classroom is an important concern for me.	1.49	0.71
Too much emphasis is placed on the integration of robotics in the classroom in my opinion.	3.43	0.71
I think students get bored with robotics topics.	3.37	0.49
As teachers, we can help to get students more interested in robotics.	1.49	0.61
Classes can provide the thought-provoking impulses towards robotics that can influence students' career choices.	1.49	0.62
I think it's good that automation technology is finding its way into the classroom more and more.	1.57	0.58
Automation technology displaces classical teaching content, which means that students do not learn other important content.	3.12	0.81

The following tables show the results in relation to the teachers' self-efficacy. The results for system handling are presented first (see Table 3).

Table 12.
Self-efficacy in handling the robots (1= strongly agree to 4= strongly disagree)

Item	M	SD
I feel confident in programming the robots.	1.82	0.635
I feel confident in describing the kinematics of the robots.	2.22	0.771
I still feel very unsure about the basics of robotics.	3.27	0.7
I feel confident in solving technical problems on the hardware (e.g. error messages due to axis errors on the robot or compilation errors in the programming).	1.82	0.808

The results show that teachers are generally confident with robots and they feel confident that they have a good understanding of the basics. They also feel comfortable with programming and solving technical problems related to the hardware. However, they find it more challenging to describe the kinematics of the robots. Self-efficacy in teaching robotics is also relatively high (*M=1,87 SD= 0,39)*, with teachers feeling capable of handling many tasks (see Table 4). However, it is worth noting that the mean scores related to the ability to motivate students who have little interest in robotics or who often experience failure are slightly lower and have a higher standard deviation.

Table 13.
Self-efficacy in teaching situations (1= strongly agree to 4= strongly disagree)

Item [I am sure that I will …]	M	SD
... be able to find an alternative explanation or examples when students do not understand something about robotics.	1.96	0.706
... be able to adapt the level of challenge of teaching in the context of robotics to the achievement level of individual students.	2.06	0.719
... be able to assess the extent to which students can understand the robotics subject matter.	1.82	0.635
... be able to get students to follow rules in class (safety rules when using equipment).	1.29	0.456
... be able to teach students the fundamental importance of robotics in the classroom.	1.65	0.597
... be able to motivate students who have little interest in robotics.	2.29	0.764
... can also motivate students who often fail in automation technology topics.	2.20	0.763
... be able to promote critical thinking with regard to robots in pupils.	1.71	0.645

Finally, the analysis of results discusses the self-efficacy in relation to lesson planning. Teachers indicate that they generally have no difficulty in finding appropriate content and engaging contexts. However, it is worth noting that the standard deviation is quite high, indicating that some teachers still find these areas challenging. This is also reflected in their expressed need for further training to teach robotics confidently (see Table 5).

Table 14.
Self-efficacy in planning lessons

Item	M	SD
I have problems finding suitable content for lesson planning on robotics.	2.71	0.816
I find it difficult to find appropriate contexts for robotics that encourage my students' interest in the content.	2.63	0.929
I need more training so that I can use robots safely in the classroom.	1.86	0.791

4 DISCUSSION

The results indicate that teachers generally feel well prepared for the challenges ahead. A successful project outcome can be considered that the majority of teachers feel confident to integrate the robotic systems into the curriculum, to program them and to solve any technical problems that may arise (Table 4). In particular, the occurrence of technical problems during the lesson, can lead to anxiety among teachers who are not specialised or who are inexperienced in this field to interact with the systems if they feel unable to control them. The fact that the teachers feel confident in solving technical problems with the robots can be considered a success of the project. This is in line with the findings on motivation to teach robotics in the classroom: The teachers surveyed find the subject interesting, enjoy teaching it and attach great importance to this topic (Table 3). As explained in Chapter 1, these motivational aspects are an indicator for getting students excited about the subject and leading to good learning outcomes. Particularly noteworthy are those aspects that broaden the view of robotics into societal contexts. Many teachers are confident in their ability to stimulate critical thinking in students and thus to address the impact of robots on societal development. As a result, the focus of the project is broadened to include social, legal, economic, historical and environmental perspectives, thus counteracting a technocratic view of technology among students that only considers the technical side of robotics but neglects the far-reaching consequences of its use.

However, it is noteworthy that many teachers report difficulties in motivating students who already show limited interest in the subject or who often experience a sense of failure. An important aspect affecting the motivation of such students is the context in which robotics is embedded. It has been observed that teachers tend to adopt a manufacturing context, which is also understandable given the widespread presence of robotic equipment in this field. However, the use of robots can also be extended to various other contexts, such as medicine and care, which could potentially attract more interest from some students. In this regard it would be interesting to see if there are gender specific effects while using different contexts in future studies. Overall, teachers often mentioned the challenge of generating appropriate ideas for contexts, which is closely related to the question at hand.

Consequently, future training programmes should priorities instructional design rather than focusing primarily on hardware and its operation. This shift would facilitate more effective teaching and learning experiences for all students. Another aspect reflected in the results is that teachers have difficulties in describing the kinematics of robots. It is noteworthy that teachers are also the least likely to address this aspect in their teaching. The different mechanisms used in robots and how to deal with them in the classroom should therefore be one of the focal points of professional development programmes. They were included into the training programme at a theoretical level (kinematics, stepper motors, sensors, etc.), but the training programme was not intended to provide any support for embedding these aspects in the classroom.

The results showed that since the beginning of the project, there has been a change in teaching and more robotics is being taught as teachers report. The project objectives have therefore been achieved in the main, although the task now is to develop clear competence frameworks for robotics and thus curriculum frameworks, and to explore their implementation in schools.

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Teaching Values in Technology Education through Co-Design

Neshane Harvey, University of Johannesburg, South Africa, neshaneh@uj.ac.za
Piet Ankiewicz, University of Johannesburg, South Africa, pieta@uj.ac.za

ABSTRACT

Co-design pedagogy appears to be gaining momentum in technology education to counteract the critique of design education for the lack of collaborative initiatives. Hence, co-design pedagogy aligns with technology education in socially constructed values that are inter-subjective and co-constructed. Socially co-constructed values imply that technology education should pave possibilities for students to learn about and practically apply value judgments to foster futuristic change agents. Like co-design, the rationale to include values, especially moral values, in technology education has grown. Incorporating values in technology education would prevent the discipline from becoming mere technical education. The exploration of the context for designing and making is one stage in the technological process to support students' exploration of value judgements. However, replacing the current orthodox pedagogy by ones in which values relating to technology and technology education are co-constructed rather than imposed requires investigation. This conceptual paper draws on the empirical findings of three co-design principles used to guide co-design pedagogy, which are then superimposed on the theoretical framework of values in technology and technology education. Hence a two-fold: Firstly, it draws on the findings of three co-design principles emanating from co-design interventions in fashion education, namely: 1) users as core and inspirational source, 2) design with users, and 3) identify user needs for integration. Subsequently, the second purpose draws linkages to technology education and proposes strategies for the teaching of moral values. Thus, the overarching research question is: How can co-design design principles be linked to and inform strategies for teaching moral values in technology education? The three co-design principles emanated from qualitative design-based research embedded in an interpretive paradigm via social constructivist methods. Following that, the linkages were a result of a superposition of the co-design principles on the theoretical framework of the teaching of moral values in technology education. The said superposition could be instrumental in reviving the stagnant framework as a contribution for technology education.

Keywords: Co-design pedagogy, Values, Technology education, Fashion design education

1. INTRODUCTION

Scholars (Barlex, 1993; Breckon, 1998; Conway, 1994; Holdsworth & Conway, 1999; Layton, 1991; Martin, 2002; McLaren, 1997; Middleton, 2005; Pavlova, 2005; Prime, 1993; Rekus, 1991; Riggs & Conway, 1991) have recognized the rationale to include values, especially moral values, in technology education. Thus, to empower students to become future agents of change, technology education should create occasions to learn about and practically apply value judgements. *The exploration of the context for designing and making* is one stage in the technological process to support students' exploration of value judgements (Martin, 2002). Dakers (2005) contends that conventional pedagogy should transform where technology and technology education values are co-constructed and not inflicted. Co-design, as a new pedagogy, is offered as a counteractive means.

While acknowledging various approaches to human-centered design (HCD), co-design, sometimes called participatory or collaborative design, is one such approach. Sanders and Stappers (2012) argue that HCD changes how one works and mindsets toward collaboration with people. HCD is an inclusive approach involving users with active collaboration and user consultation throughout the design development phases (Stappers & Visser, 2007; Hanington, 2010). Consequently, Steen (2011) claims that with an HCD ethos, designers aim to collaborate with or learn from users with the specific intention of developing products that align with users' practices, needs, and preferences. However, HCD is not the same as user-centered design. Scholars argue that HCD reflects a sense of humanness and "concern for people" with users as collaborators, but user-centered design designates "people's roles as users" therefore, users are study subjects (Sanders & Stappers, 2012; Steen, 2011:45). As an HCD approach, co-design is a fresh design discipline where a user significantly contributes and collaborates to counteract the values of the 'hero-designer' (Harvey, 2018, Harvey & Ankiewicz, 2022; Ordaz et al., 2018; Stables, 2017).

Subsequently, in technology education, co-design pedagogy appears to be gaining momentum (Harvey & Ankiewicz, 2022; Ordaz et al., 2018), which resonates with Fleming's (cited in Stables, 2017:65) critique that design education supports "disciplinary silos", lacks collaboration, understanding core values of inclusion and interrogation around "who designs" in the epoch of collaboration. As such, co-design pedagogy aligns with Dakers (2005) stance of socially constructed values that are inter-subjective and co-constructed in technology education. Co-design pedagogy is substantiated within Martin's (2002) stage: *the exploration of the context for designing and making* because it is at this stage in the design process that students can socially co-construct value judgements with users to offset individual values that inform later stages.

HCD, especially the three co-design principles were conceived and tested empirically for co-design interventions in university-based fashion design education as part of a doctoral project (Harvey, 2018), adds value to pedagogical activities and teaching values in fashion design education. However, replacing the current orthodox pedagogy by ones in which values relating to technology and technology education are co-constructed rather than imposed requires investigation.

This conceptual paper draws on the empirical findings of three co-design principles used to guide co-design pedagogy, which is then superimposed on the theoretical framework of values in technology and technology education. Hence a two-fold paper aim: Firstly, it draws on the findings of three design principles emanating from co-design interventions in fashion education, namely: 1) users as core and inspirational source, 2) design with users, and 3) identify user needs for integration. Subsequently, the second purpose draws linkages to technology education and proposes strategies for teaching moral values. The underlying research question is: *How can co-design principles be linked to and inform strategies for teaching moral values in technology education?*

The discussion shifts now to the three co-design principles for co-design interventions in university-based fashion design education.

3 DESIGN PRINCIPLES FOR CO-DESIGN INTERVENTIONS

3.1 Research methodology

The methodology utilised qualitative design-based research (Amiel & Reeves, 2008; Collins et al., 2004; Plomp, 2010; Reeves, 2006) rooted in an interpretive paradigm via social constructivist methods. In a doctoral project (Harvey, 2018), scholarship on HCD was reviewed to establish design principles of co-design for teaching and learning interventions. The critical analysis of the design principles was done in the doctoral project (Harvey, 2018). While several design principles emerged from the critical analysis, three distilled design principles are considered for this paper: 1) users as a core and inspirational source, 2) design with users, and 3) identify user needs for integration with design. The first design principle (DP1) places the user as the core and source of inspiration; hence, the focus is on the user as the nucleus of design and inspirational source and not a subject of study. The second design principle (DP2) is about collaboration between users and designers in that users are active and continuously involved partners in the design process and design should unfold 'with' users and not 'for' users. The third design principle (DP3) is about identifying and addressing user needs, including values, goals and preferences through socially engaged dialogue as input into the design process before seeking to address those needs, goals and preferences (Harvey, 2018).

DP1 acts as the starting point input, the second (DP2) is about collaboration, and the third (DP3) relates to user needs as value judgements. These three design principles were selected for this paper because of the specific link to the exploration of the context for designing and making. They were used to design two teaching and learning interventions, a pilot and main, which took the form of design projects for implementation with first-year fashion design students at a South African urban university. For the pilot intervention, the project duration extended over a four-week block, but the main intervention extended over a seven-week block. Both the pilot and main interventions were made up of both contact sessions with educators and non-contact sessions for self-directed student learning (Harvey, 2018).

To engage with the exploration of the context for designing and making, students could not draw on secondary visual inspiration and manifestations of personal values and self-expression. Instead, pedagogical strategies required students to role-play in design teams of two, with one student assuming the designer position and the other that of the user with the independence to choose design team members and positions. While acknowledging that students role-playing as designers and users may possibly yield biases, the purpose was to construct a culture of teaching and learning and an alternative mind-set regarding the needs and values of users to combine with that of the designer. In the same light, consideration was given to ethics if real-world users were involved. Hence, pedagogical strategies necessitated design teams to: 1) engage in qualitative discussions to establish the context of design use, user needs, preferences, goals, and design requirements, and 2) in collaboration, co-design, and develop a product with the user. While HCD expects collaboration with actual users, the principles of studio-based pedagogy accommodated a simulated co-design situation.

Three participant sub-sets formed part of the purposive sampling: students, educators and a researcher. Twenty-four first-year fashion design students participated in the pilot and 23 in the main intervention and two university educators (representing university lecturers) who taught design or product development activities. While design teams comprised of two students for the pilot intervention, one student de-registered and therefore for the main intervention, one design team had one designer and two users. The principal author served the dual role of the primary observer in data collection during the teaching and learning interventions and the secondary role of designing the two interventions in collaboration with both educators. All participants gave informed consent for qualitative data collection, including participant observation, student semi-structured questionnaires, and educator semi-structured interviews. Participant observations aimed at documenting the design team's design process activity tasks and how these actions extended in the exploration of the context for designing and making. The first-year students self-administered hard-copy questionnaires to ascertain their views and experiences regarding the three design principles. Similarly, individual, digitally recorded, face-to-face, semi-structured interviews were conducted with the two educators.

Empirical data were analysed via a constant comparative method (Merriam, 2009) with the application of Atlas.ti guided by Saldaña's (2016:14) "streamlined codes-to-theory" model via first and second coding cycles. For the second purpose of the paper, the empirical finding of the three design principles was superimposed on a conceptual meta-synthesis of technology education to draw linkages to technology education and proposes strategies for teaching moral values.

3.2 Empirical findings

A summary of the key findings is narrated around the above-mentioned three design principles; however, detailed descriptions and a more critical approach are available in a previous publication (Harvey & Ankiewicz, 2022). To support the findings, participant data quotations are included. Letters and numbered codes are assigned as pseudonyms to differentiate between participants. E2 represents educator number two, SU1 indicates student user response, SD1 is the student designer in the same design team, and PO reflects participant observation field notes carried out by the principal author.

3.2.1Users as core and inspirational source (DP1)

Findings around DP1 were previously deliberated (Harvey et al., 2019), but the discussion pertains to values for this paper. Key findings reveal an unexpected way of thinking about and practicing design through understanding, consideration and value judgements of design with empathy. The findings are expressed in statements such as an "eye-opening" (SD6) strategy that supports "out-of-the-box" (SD7) thinking. Intrinsically, the consensus was a mindset shift towards design with empathy due to greater emphasis on user value judgement to eradicate the "notion that they [students] are star designers as seen in media" (E2). Student designers and users confirmed an empathetic approach because of opportunities for designers to "empathise throughout the process making them [user] be part of the entire process" (SD8). Inherently, the hero-designer values metamorphosed to be "more considerate of the user" (SD9) and user value judgements to drive design. Likewise, users expressed that their designers demonstrated empathy by taking a "closer look at understanding another person" (SU4).

3.2.2Design with users (DP2)

DP2 replaces traditional teaching practice because "... it's a novel new way of doing things which is going to become much bigger in the future" (E1). DP2 was valuable and mind-changing because user values, voice, and participation in the design process "changed their [students] mind on the role that the user can play in the design process and the benefits that come with involving them" (E2). Student users concurred that the reshaping mindset manifested in an improved design approach as exhibited in comments: "user and designer became more open-minded" (SU9) and "designing with the user brings about a better approach" (SU5). As such, students discovered the value of user engagement minus the assumption that, as designers, they know peoples' needs. Students preferred DP2 because design practice developed a better alignment with user needs and values than the hero-designer approach. Hence, the consensus of new insight about design emerged through negotiated value judgments, agreement in decision-making, inclusivity and collaboration rather than engaging in a hero-designer-driven approach and thinking whereby the designer draws inspiration from predominately visual imagery and designs with and for personal values and self-expression. Student comments reflected these findings: "we both have different tastes and values but working together made the design much better" (SU2), and "decisions throughout the process were made with the user" (SD10).

3.2.3Identify user needs for integration with design (DP3)

In this paper, the intention was not to present the results of the users' different needs and how these needs were integrated with design. Rather the intention is to deliberate on the findings pertaining to the holistic views and experiences regarding DP3 itself.

To begin *the exploration of the context for designing and making*, in the input stage, designers engaged in primary empirical research to move away from the tradition of secondary visual inspirational research, hence, moving from the old to new. Therefore, designers engaged users in qualitative discussions to collect information about user needs, goals, preferences, and context of design usage as echoed in the excerpt: "designer was very engaging in conversation with user ... started to collect information from user ... probed the user to get clarification" (PO). The documentation and synthesis of primary research in student design journals were well documented with "data [that] was rich" (E2). Hence, primary qualitative research instituted exploration and understanding to identify design criteria without personal value judgements. One student designer remarked, "we were able to discern her actual needs and context of use. The main design criteria are not just extracted from hypotheses" (SD7). This influenced social values of rapport building, relationship development, and harmony in a non-judgemental manner, as conveyed in the remark: "the user was able to communicate with me ... without shying away from being judged or questioned" (SD8). E2 considered primary research as evoking an "empathic approach in which the designer had to empathise with the user in order to gain a better understanding of what the user required from their product (E2). These findings incline value judgements and thoughtfulness towards the other person.

Identifying user needs was “beneficial” (E1) for students’ critical analysis and reasoning regarding social importance. Hence, educators could not enforce personal values because designers justified why they could not digress from their user’s needs as echoed: “in class when I made suggestions, let’s change this or take this particular direction ... they tell me no, the user needs this so we can’t really deviate too much from it” (E1). The implications are student-directed active learning, autonomous thinking, critical analysis, and rationalization rather than passive knowledge recipients.

Through active learning, students integrated primary research to prompt co-design activities by exploring ways to engage with design activities to ensure design solutions focused on user needs. For students, primary research and incorporation with design provoked insight about research to inform design practice as echoed: “by doing primary research, I was able to get qualitative information on the user and that formed a strong bases (sic) for our design” (SD10) which afforded the opportunity to “push the boundaries” (SD4) and surpass personal values by “making sure that the user is satisfied” (SU6). Hence designers could not “design what they like” (E1) from personal values because they could not “solely focus on their own preferences and style” (E2).

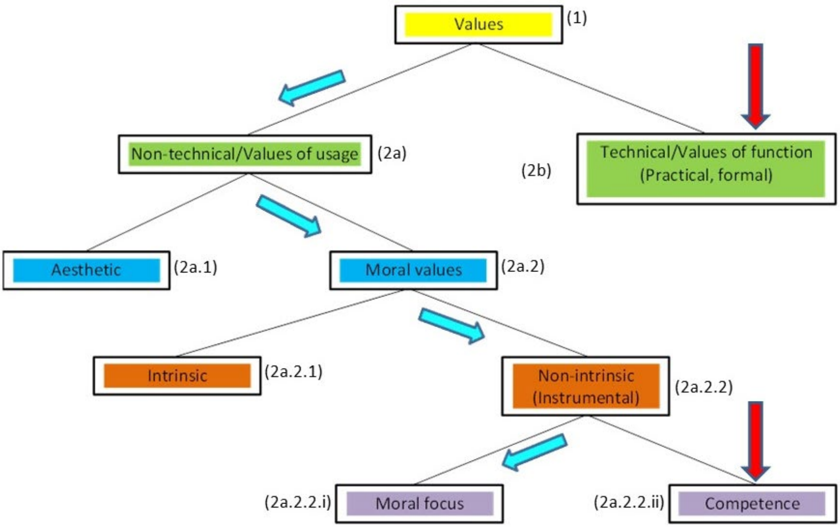
The authors support the representation of technology education as ‘technology informed by design’ (Jones & De Vries, 2009) as found in, for example, Australia, England and South Africa (Ankiewicz, 2021; Jones et al., 2013). Thus, design is a common key tenet of both technology (De Vries, 2018) and fashion design (Harvey & Ankiewicz, 2022). Furthermore, the intervention in fashion design education was based on the philosophy of technology and technology education by applying the technological design process in fashion design (Harvey, 2018). Therefore, although contextualised within university fashion design education because of the context-specific nature of the research design, this new pedagogy may well apply to teaching values in school-context technology education. The various types of values in technology education will be discussed in the next section.

4 TYPES OF VALUES IN TECHNOLOGY EDUCATION

It has already been mentioned and acknowledged in the literature on technology and technology education that technology is value laden. The research methodology employed for this part of the paper was a systematised literature review followed by a meta-synthesis of a selection of literature on the theoretical framework of values in technology and technology education. Firstly, a systematised literature review was firstly conducted in the International Journal of Technology and Design Education (ITDE), the field’s top tier journal (Williams, 2016), using the search terms ‘values’, ‘value-free’ and ‘value-neutral’, ‘aesthetic’, ‘attitudes’, ‘beliefs’, ‘efficient’, ‘effective’, ‘ethic’, ‘environment’, and ‘judgements’. The time perioded covered the inception of ITDE up to 2018 when the author was on sabbatical. Secondly, the result of nine ITDE articles directed us to three more technology education journals (four articles) and three book chapters which focus on the theoretical framework of values in technology and technology education (cf. Buckley et al., 2022). Parts of the theoretical framework that underpins this section have been published elsewhere in a different format like the implications of Andrew Feenberg’s critical theory of technology (Ankiewicz, 2019), and the affordances of a human-centered design pedagogy (Harvey & Ankiewicz, 2022) for the teaching of values in technology education.

Technology exists because of human activity and is developed and used in social and environmental contexts. As such, it is shaped by communal beliefs, values, and attitudes of individuals, organisations, and society and, in turn, has a significant effect on shaping culture and the environment (Conway, 1994; Martin, 2002; Stables, 2017). Technology education based on determinism and instrumentalism that views technology as value-neutral will reduce technology education to technical education (Conway & Riggs, 1994; Hansen, 1997; Martin, 2002; Stables, 2017). Literature reveals distinct types of values in technology and technology education, for example aesthetic, economic, social, moral, environmental, political, and spiritual values (Jones et al., 2013; Martin, 2002; Pavlova, 2005). Scholars have classified these values into broader categories. Figure 1 visually summarises the current theoretical framework of values (1) in technology education.

Figure 1.
Types of values in technology education



Accordingly, there are two major types of values in technology education, namely technical values (2a) and non-technical values (2b) (The bracketed numbers refer to the relative position in Fig. 1). Scholars use various synonyms for these types of values. Formal, practical, and technical values (Pavlova, 2005) or values of function (Rekus, 1991) are synonymous and referred to as technical values, which relate to value judgements concerning the functionality/efficiency and effectiveness of technology.

Non-technical values (Pavlova, 2005) or values of usage (Rekus, 1991) are judgments concerning the morality of action related to the usage of technology, which may only be done by acting individuals themselves (Rekus, 1991). These values can be divided into aesthetics (2a.1) and moral values (2a.2). Although some non-technical values (for example aesthetics) are mentioned as part of technological knowledge, moral values are not.

Moral values can be further divided into intrinsic (technical or economic and good in itself) (2a.2.1) and non-intrinsic or instrumental values (as a means to an end) (2a.2.2) Pavlova (2005). Instrumental values encompass such concepts as ambitious, open-minded, capable, helpful, honest, imaginative, intellectual, logical, responsible, and self-controlled (Pavlova, 2005). Technology education mostly deals with instrumental values, of which two major kinds are those with a moral focus (2a.2.2.i) and those related to competence or self-actualisation (2a.2.2.ii). Pavlova (2005) also distinguishes epistemologically between knowledge about and knowledge within technology. The former is aimed at understanding the nature, values and ethical issues of technology in the complex relationship between person, society and nature. It is thus closely related to STS studies and includes analyses of technology at inter-disciplinary, disciplinary and practical levels within different areas. Knowledge within technology includes knowledge about objects and processes, and requires of students to design and make, analyse, use and maintain products (cf. Khunyakari, 2019).

According to this theoretical classification of values, technical values are strongly dominating in most approaches in technology education, but without explicitly referring to them as values (Pavlova, 2005). Teachers put the highest priority in design and technology classrooms on the teaching of technical values (2b) and values related to competence (2a.2.2.ii) take priority over moral values (Holdsworth & Conway, 1999; Pavlova, 2005) (refer to the red arrows in Fig. 1), with their hierarchy of values resembling the following: technical, aesthetical, economic, environmental, social, cultural, moral, and political (Pavlova, 2005). The priority and emphasis assigned by teachers can easily reduce technology education to technical education.

Pavlova (2005) argues that moral values should take priority in technology teachers' hierarchy of values. Moral education will be emphasised if technology education includes technical (formal, practical or values of function) and non-technical values (instrumental or values of usage) (Rekus, 1991). Teachers need to introduce students to the kinds of moral dilemmas they will face in everyday life as a direct result of the spread of technology (Dakers, 2005). Table 1 lists some examples of such moral dilemmas against specific moral values.

Table 1.
Kinds of moral dilemmas students will face in everyday life

Moral values	Descriptions of examples	Specific examples
Honesty, responsibility and integrity	Moneymaking, substandard design solutions at the expense of quality	Preventing structural failure of buildings, bridges, towers etc.
Caring, fairness and respect	Bias towards gender, disability, cultural and religious groups in design solutions	Ensuring access for people with disabilities
Work ethic (including being punctual, responsible and reliable)	The negative impact of design solutions on individual users,	Managing waste, including air and noise pollution

	communities and the environment

In the next section we argue that emphasising a co-design pedagogy, based on the above-mentioned three design principles, might be instrumental to create a shift from the dominance of technical values (2b), as well as values related to competence (2a.2.2.ii), to non-intrinsic values with a moral focus (2a.2.2.i) in technology education (refer to the turquoise arrows in Fig. 1). As the findings of this paper, the three design principles will be linked to the theoretical framework of teaching values with a moral focus in technology education, and the linkages will be indicated by showing the relevant design principles in brackets.

5 FINDINGS: LINKING THE THREE CO-DESIGN PRINCIPLES TO TEACHING VALUES WITH A MORAL FOCUS IN TECHNOLOGY EDUCATION

As moral values are inherently part of acting individuals themselves (Rekus, 1991), the most frequently proposed way of teaching values in technology education is to encourage students to think about values themselves (DP3) (Pavlova, 2005). Technology teachers and students need to be explicit about the values involved at all levels of technology and to clarify, justify and debate their choices (Conway, 1994; Conway & Riggs, 1994; McLaren, 1997; Riggs & Conway, 1991). Technology teachers should be upfront about the collective values guiding technological development in society and in technology education, as well as the specific values which guide both technologists and prospective technologists in schools (Riggs & Conway, 1991). Students should have opportunities of valuing technology independently without teachers imposing their own sets of values and norms (DP3) (Rekus, 1991).

Within Martin's (2002) stage of *exploring the context for designing and making*, the choice of the starting point of a technology project is important to show the connections between context, technology, and value judgments (DP1) (Conway & Riggs, 1994; Martin, 2002). The teacher should choose an issue or project brief that relates to the current value system of the students (DP3), taking psychological and sociological aspects of the students' situation into consideration (DP1, 3) (Rekus, 1991). In this regard, technology teachers may capitalise on the pedagogies associated with science, technology, and society (STS) studies. STS studies may promote a critical approach to technology in curriculum documents by considering the relationship between society and technology (Pavlova, 2005). STS teaching commences with everyday issues instead of organizing technology lessons around concepts and processes (DP1, 3). Furthermore, interdisciplinary project work and integrated STS programmes may create a context in which students construct their relationship with technology and learn about its topical, motivational, and interpretative meaning (DP2, 3) (Hansen, 1997). It may also require some integration across artificial subject boundaries of the school curriculum (DP2) (McLaren, 1997). It is important for technology teachers to encourage critical thinking and questioning so that students are aware that technology is related to people, society, and the environment (DP3). How students' value technology will shape their future (DP3) and they are entitled to discuss such issues in the classroom (DP1) (Jones et al., 2013; Martin, 2002).

6 CONCLUSION

Following from the findings which emanated from the qualitative design-based research in fashion design education, and congruent to Dakers' (2005) call for a new pedagogy in which values relating to technology and technology education are co-constructed rather than imposed, a pedagogy based on the three design principles might be conducive to affect a shift from the dominance of technical values and competence as non-technical values to moral values. Resulting from the superposition of the three empirically researched co-design principles on the theoretical framework of values in technology and technology education, we propose new pedagogy for co-design to teach moral values in technology education that comprises the following: When introducing a technology project to students for the stage of *exploring the context for designing and making* divide them in pairs of two where the one assumes the role of designer and the other one the role of user. For example, if there are 20 students in a class then essentially there would be ten users and ten designers. As another example, with larger groups students could be paired in groups of three with either one designer and two users or vice versa. The technology teacher must ensure that the curriculum, learning outcomes and activities are planned to accommodate for: 1) users to be the core and inspirational driver, 2) for students to engage in primary qualitative research with users to explore their views and values for integration with design, 3) create opportunities for co-design activities and 4) place less emphasis on the functionality/efficiency and effectiveness of students' products. Likewise, teachers should change their ideological beliefs, imposition of personal value-judgements and pedagogical strategies to accommodate for student engagement, co-constructed values, and collaboration. This proposed new co-design pedagogy in technology education should be further explored at school level through action research cycles as further empirical research in future.

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Engaging object agency: new ways of design learning and being for young people in the museum

Alice Hellard, Goldsmiths University of London, alice.hellard@gold.ac.uk

ABSTRACT

This research investigates object intra-actions with young people on school visits in the UK design museum. As an important aspect of designing, agency in relation to learning is under-researched in museum studies, and this is especially lacking in research that focuses on learning during secondary school visits to design museums. Further exploring agency through religious-political dimensions, another under-researched area is religious influences in museology broadly, and in museum learning in particular. These influences are pertinent to learner and object agency due to their historical proscription of certain values and structures to knowledge and experience of the design object and its representations in the museum, and as such they co-constitute the entanglement of this research. The research aims to disrupt the status quo by using a design and new materialist methodological approach to make sense of and, where possible, make visible intra-actions between objects within this entanglement.

This paper is intended as a discussion piece which examines the historically imbued nature of design learning for young people in school visits to the museum, including some analysis of contemporary practice in London museums. This frames a number of key questions to be explored further through the conference presentation. Agential realism (Barad, 2007) underpins the theoretical-methodological framework which also supports my position as learner-researcher, and this positioning is further enhanced by my professional experience in London museums, schools and the university. The research identifies alternative pedagogies for both schools and museums in this context that are co-located between design and technology learners and museums as entangled producers of knowledge. This is a radical re-imagining of design pedagogies in museums and school classrooms that contributes to the multi-stakeholder dialogue on decolonising methodologies within design and technology education.

Keywords: museum-based design pedagogies, object-based learning, design and learner agency, decolonising design & technology learning

1. INTRODUCTION

Taking place in London, UK, this research is focused on entanglements of learning between design and technology (D&T) departments in schools and museums that house design-centred collections – for example the Design Museum and the V&A Museum – and considers how and where learner and object agency is located as part of a school visit. This paper is intended as a discussion piece that explores some of the unseen agencies that may be active within this context. It initially considers the nature of informal learning in museums, framed by the historical development of UK museums out of Christian-colonialism (Findlen, 2004; Barrett, 2012), suggesting that in the contemporary museum the agency of objects can be inhibited (Morgan, 2017). The paper goes on to discuss the relevance of agency to learning and pedagogy in the design museum (Hohenstein and Moussouri, 2017; Charman, 2010) and to design learning in schools (McLain, 2022; Barlex, 2014). In this research agency is defined as the ability to act in the world, and in the literature review pedagogy refers to informal learning apparatuses that include object selection, methods of display and museum architecture, as well as some of the more formal approaches by museum learning teams. In the second part of the paper, I discuss current approaches for design learning for young people in museums, bringing together related theory in design and technology education and my own experience as a design and technology teacher, a museum learning facilitator and a teacher educator. The paper concludes with a brief outline of the practice research and framework-methodology, which includes agential realism (Barad, 2007), object oriented ontology (Harman, 2018) and ontological designing (Willis, 2006), framing a number of questions for conference participants to consider. Design methods and the agency of design (Fry, 2020) are central within both the research entanglement and the framework-methodology.

8 LITERATURE REVIEW

8.1 Learning and pedagogy in the museum

Museums are sites of learning in both a formal, cognitive, sense, and in ways that are much broader, including the emotional, attitudinal and aspirational (Hohenstein and Moussouri, 2017), that bring learning together with communication, culture and identity (Hooper-Greenhill, 2007). Influential theories include Dewey's experiential learning (Dewey, 2015), Piaget's (1951) constructivism and Vygotsky's (1978) social constructivism, with Freire's (1996) critical pedagogy and associated theory also widely cited in the field for its influence on democracy and social justice. What underpins each of these interconnected approaches is the conception of learning as personal meaning making, or interpretation, which is bitty and takes place gradually (Hohenstein and Moussouri, 2017). Falk and Dierking (2018) argue that learning from museums takes place across three distinct contexts (personal, social and physical) over long periods of time, and this can be likened to the ongoing process of becoming in critical pedagogy (Freire, 1990, 2000) and Dakers' (2014) theory concerning the development of technological literacy.

Museums the world over are considered to have pivoted in their purpose from the 1990s, now focused on the experience of audiences over the knowledge contained in their collections (Hooper-Greenhill, 2007). However, there are institutional struggles and within the museum learning is considered to remain a contested area (Hein, 2012). For Kristindóttir (2017) there is tension between pedagogy and museology, with pedagogy a word often left out of discussions within institutions and the wider field regarding visitor engagement. This may be indicative of the politics and silos formed as a result of funding and reporting structures (Dewdney et al., 2013) and of perceptions of knowledge and authority (power) between curating and learning within institutions (Wood, 2019). I am initially considering museum learning as an holistic and core aspect of museum practice. This is because viewing the learning experience as a whole also includes the experience of the space, methods of display, and the selection of objects, for example, all of which museum learning professionals have little control over (Dewdney et al., 2013).

8.2 Religious-political object orientation

The history of museum development in Europe comes out of a long tradition of Christianity and education (Barrett, 2012) and while contemporary museums are secular in that they are outwardly neutral to religion (Buggeln et al., 2017), this literature points to a complex entanglement suggesting that some of the museum's methodologies remain imbued with Christian and, since the mid-nineteenth century, Christian-colonial influences. Modern museums were seen as public structures of authority to educate the masses and demonstrate progress and power (Findlen, 2004), but Christian influences also informed exhibition design. Perceived as the highest order sense, sight was foregrounded by the Jesuit educational system in the early period of museum development, whose optical formatting techniques included chronological display (Preziosi, 2004) and the emblematic use of a heading, image and panel of text (Potteman, 2000). While there are arguments about the extent to which other senses are valued in contemporary culture, and the possibility that the dominance of visuality has been overstated (Howes, 2003), it is also acknowledged that contemporary design museums have tended to borrow this preference for visuality from the art museum (Charman, 2011).

In the design museum, forms of display are considered particular to the domain of design, and as such they help to assert that design is "the reification of ideas into material form" (Charman, 2016, p.139). In the contemporary museum the visitor's experience of design remains typically through looking (Charman, 2011) and reading an interpretation label, often within a chronological and thematic system, which I suggest can be aligned with the Jesuit emblem (Potteman, 2000). However, Fry points out that the reification of design constitutes a misunderstanding of the nature of design, because it casts shade over the unseen ontological assemblages and agencies of design (Fry, 2020). Preziosi (2014) notes that reification in the museum represents a separation between subject and object, whereby the object is staged outside of its own history; a mere representation of itself and the socio-historical subject it has come out of. This, he argues, demonstrates a secular religiosity that confers symbolism onto the object which is further generated through the hierarchies of academic disciplines (Preziosi, 2014). Visual culture is considered to dominate the contemporary museum landscape (Promey, 2017), and to have contributed to the museological separation between subject and object, which constitutes a certain kind of colonial 'othering' (Classen and Howes, 2006).

Beyond the design object, it is argued that many museum objects with religious origins are displayed in the contemporary museum as ethnographic artefacts, stripped of their spiritual meanings in favour of beauty or historical significance (Paine, 2014). Morgan (2017) suggests that this echoes curatorial habits of the colonial period, whereby objects were abstracted from embodied contexts in order to demonstrate progress and power, implicating Christianity and it's "promotion of the ameliorating effects of civilisation" (Morgan, 2017, p.121). Promey (2017) contends that museum institutions have always been part of the process of secularisation, with certain religious values deliberately conferred through museum display in the eighteen and early nineteenth centuries. This is argued to have been a very effective strategy for democratising and secularising modern social life, which also had the effect of obscuring (though not eradicating) religion and belief (Preziosi, 2004). Nye (2019) explains that the religion-secular relationship emerged through the process of colonialism, with each needing the 'other' in order to "colonise, civilise and defeat" (Nye, 2019, p.17).

It is considered no coincidence that recent interest in the representation of religion in museums comes at a time when secularisation theory is also debunked (Promey, 2017). Museums are considered by some to be secular sites of religiosity; the sacred space or 'temple' (Duncan and Wallach, 2004) which presupposes public faith in the power of the museum and the museum objects' authenticity or truths (Suares, 2019). Museum architecture is argued to design certain religious values and beliefs into the museum experience (Duncan and Wallach, 2004), which is just one way in which colonial power and forms of 'monotheistic universalism' are thought to be visible in the contemporary museum (Suares, 2019). This, I suggest, demonstrates something of the agency of design (Fry, 2020) in-relation with Christianity and colonialism within this context. Hervieu-Léger (2006) points out that the casting of social movements or activities such as sport, for example, as secular religions is based on a social inscription of sacredness and meaning-making which, in the Western context, is derived from a Christian model, and therefore so-called secular religions do not in fact replace the Christian tradition but continue it. While I am not explicitly involving religion or religious objects in this research, suggestions that an effect of Christian-colonialism and secularisation is to mask meaning, and that museology has a tendency to separate subject and object, have implications for learner agency.

8.3 Entangled agencies

A relatively young academic subject, the history of design has to a large extent been determined by industrialisation and globalisation, and therefore does not escape its own difficult encounters with representations of people and places that are tied to colonialism (Williams, 2007; Msila and Gumbo, 2016). Design is also contrarily seen as both profoundly secular by its nature, and as having "replaced the hand of God," in that once initiated by human activity, design can continue to design itself (Fry, 2018), and people (Willis, 2006). Fry argues that this fact, and the ethics of design, are little understood by the structures of design, especially so in design education. "Design's agency does not usually come from it being mobilised with a clear vision of consequences, but rather from its power as an unrecognised structural inscription" (Fry, 2020, p.3). According to Fry, design is everywhere, and its agency can be found, at least in part, in this positioning as always underneath.

In design and technology education in UK schools, learner agency is positioned within critique (Keirl, 2016), context (Stables, 2016), and the process of reflection and action within design praxis (Barlex, 2014), with knowledge for action foregrounded as a distinguishing feature of the subject (McLain, 2022). In museums, visitor/learner agency is under-researched; while it is explicitly addressed by museums for the purposes of visitor engagement and marketing, agency is far less understood in respect of learning (Hohenstein and Moussouri, 2017). In relation to design learning in the museum Charman (2011) discusses Bal's theory of the 'expository agency' of the exhibition, whereby the exhibition itself is characterised as an actor doing the 'speaking' through the accoutrements of curation and exhibition design. In this theory the agency of the visitor/learner is implicitly entangled with the agency of the exhibition, which itself renders invisible the agency and selections of curators (Charman, 2011). Against the perception that contemporary museums continue to convey Christian-colonial attitudes (Morgan, 2017; Suares, 2019) that also decontextualise the object and obscure its networked relationships between human and non-human things (Morgan, 2017), this kind of exhibitionary agency might be seen as problematic. Within the museum this can, I propose, suggest a separation of subject from object through the predominant use of visual representation (of ideas as well as people and places) as a methodology. Representation is argued to be a problem as it serves to reflect 'sameness' and reproduce associated problems rather than to find new meanings (Barad, 2007). In this dynamic the agency of the museum object itself has begun to be considered within the museum (Sherritt, 2019; Hood and Kraehe, 2017), and this is one of the central questions of my research. In considering the historical-present context of museum architecture, object selection and display, alongside more formal design pedagogies, I aim to set the scene for the investigation of the agencies of the design object on display in-relation with the agencies of learners.

9 DISCUSSION

9.1 Design learning in and between schools and museums

Object-based learning is a distinguishing feature across museum-based learning and the design and technology classroom in the UK, though the nature of both can be decidedly different. For schools there is a little literature that addresses how objects can be used to enhance design learning (Stables, 2000), and some critique of school practice around product analysis (McLellan and Nicholl, 2011). In my experience as a teacher and teacher educator this critique highlights some of the issues with prevailing approaches in UK secondary schools, where product analysis activities can be cursory and formulaic and can involve students looking at images and representations of objects rather than handling the objects themselves, often as part of the 'research' stage of a design process. Object-based learning has an extensive research base for museums and higher education (Paris, 2002; Farrelly and Weddell, 2016; Chatterjee and Hannan, 2017), and in UK museums there has been some research into approaches to object based learning as part of the distinctive nature of museum-based design learning workshops for young people (Charman, 2010). However, the identity of formal design museum pedagogies for young people is not extensively researched and this, alongside learner agency, highlights a further gap in the literature.

In parallel with the decline of D&T in UK schools in recent years, there have been significant developments in the forms of engagement by typological museums with schools, with some institutions explicitly advocating for the school-based subject in the face of such challenges (Block, 2017). Delivery models include self-guided visits, workshops for school groups, 'outreach' work in schools and online resources. Notably there are now at least four national design competitions for secondary aged students led by museums and cultural organisations, most of which focus on human-centred design contextualised by real-world challenges or themes. Programmes with a national reach such as these are seen to be important vehicles for driving engagement (a key performance measure for museums); they are relatively inexpensive to resource because they are driven by digital engagement (Murphy, 2021) and can be high profile and wide reaching (Spielman, 2019). They can also drive direct engagement with museum professionals and collections, either through in-person school visits to the museum or through online remote learning provision. For schools, the competition model is often seen as beneficial as it provides resources for teaching about and for design in a semi-structured way, and often includes input from practising designers which helps schools to address frameworks mandated by UK government policy (see Gatsby Benchmarks, for example).

In addition to these models of engagement, standalone in-person visits are offered by museums, which I am focusing on in this research. From my experience in London museums, these typically involve a free choice visit to one or more galleries and may include a workshop session delivered by a museum learning facilitator or educator. During free choice visits schools can draw from 'off the shelf' supporting resources provided by the museum, which may relate explicitly to themes in collections or a current temporary exhibition, for example, and workshops can be selected from a menu of themes. Despite being seen as sites of informal learning and not bound by the formal assessment requirements of schools (Hooper-Greenhill, 2007), museums increasingly make clear links to the national curriculum and relevant key stages on many of their resources and through their programmes (Briggs, 2022). In my experience as a D&T teacher and museum educator museums can help to emphasise the connections between design and technology, and technology and society, while also raising the profile of designing activities in schools.

However, through my practice I have observed some conflicting relationships between schools and museums. During one museum session I led, the class teacher sat in the corner of the room for the duration of the 90-minute workshop, opting to observe their Year 9 students participating in the learning activities. At the end of the session, we engaged briefly in conversation as the class filed out, when the teacher exclaimed "you mean *you're* a D&T teacher?" There were conversations with museum colleagues at the time about school visits being seen as a 'nice day out' and during other sessions I perceived siloed discourses about design between design professionals, museum learning facilitators and school teachers, as well as frustration from museum colleagues about siloed practices within the museum. Rather than point to the passivity of teachers, all of this seemed to highlight conflicts between the pressures of school-based curriculum delivery in terms of procedural and factual knowledge and the tacit and haptic knowledge that museum learning programmes can implicitly and explicitly invoke, as well as to draw attention to perceptions of the authority of the 'expert' other from within (and between) institutions. I suggest that the relationship between schools and museums is complex and in focusing on content has the potential to decentralise personal meaning-making for young design learners.

10 CONCLUSION

As discussed in the literature review, in school-based design learning agency is often directed towards and through human-centred designing activity, through critique, context and decision making, and in my experience this is also true in museum-based approaches. However, agency is a dynamic network that also involves identity, culture and belief within our ability to act in the world. Diversity and inclusion are increasingly addressed within museums and schools through content and representation, which makes differences visible, but practices that connect the networked agencies between learners and objects can be harder to see within the museum context outlined above. Within current discourse on decolonising school-based design learning it is considered important to identify methodological approaches that go beyond representation (Prajapat et al., 2022). Prioritising methodology, this research seeks to make visible and reposition agency in design learning in museums within the full entanglement of objects involved, in ways that disrupt current programmatic and/or disciplinary focused approaches to learning about design through objects.

In Autumn 2023 I will undertake the practice research with a group of Year 12 design and technology students and their teacher. Theirs is a large comprehensive school located in east London, serving a diverse community with a very high proportion of students with English as an additional language and a high number of students with SEND (Ofsted, 2018). The framework-methodology for the practice draws from object oriented ontology (OOO) (Harman, 2018), ontological designing (Willis, 2006) and agential realism (Barad, 2007) in order to identify the hierarchy of objects involved in the research context and make visible the possible intra-actions within this entanglement. Using design methods and processes that also make visible the agency of design (Fry, 2020) participants will engage in a number of workshops, including a visit to a London museum, using design to respond to intra-actions they identify. In the conference presentation I will illustrate the approaches taken to reposition and reframe learners' relationships with objects on display. As stakeholders in design learning from a range of sectors and disciplines, contributors and participants at PATT40 are located within the research context and can make a valuable contribution to the research. I am keen to explore and discuss our collective, individual and different perspectives and I hope that this paper and the following questions provide a starting point for dialogue:

11 KEY QUESTIONS

(i) How do you locate learner agency in design and technology education?
(ii) How and where is the agency of the object located in design learning?
(iii) How recognisable to you are the issues discussed here around power, agency and authority in contemporary museum- and school-based learning about design?
(iv) How do we do and experience dialogues about religious and political issues and design with young people?

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To See Reason: Technology Teachers' Guidance and Students' Reasoning in the Design Process

Ellinor Hultmark, KTH Royal Institute of Technology, ellinorh@kth.se

ABSTRACT

In this study, the aim has been to explore teacher guidance in relation to students' reasoning in the design process. It is important that technology education develops students' reasoning in design so that the students can learn to draw conscious conclusions and to make the thought process behind these conclusions explicit. The teacher's support is pivotal to this learning. However, research on teacher guidance when students reason within technology education is limited. Nonetheless, gaining knowledge about this would support further insights in how to develop students' reasoning in design. Data has been collected through two classroom observations of lessons in technology education in Swedish secondary schools. Video and audio were recorded using two cameras and teacher-mounted and student group microphones. Transcribed video and audio data were analyzed through thematic analysis. In the results, the teacher interventions have been described and presented in relation to the important reasoning types in design; means-end reasoning and cause-effect reasoning. Findings indicate that the students' reasoning is more explicit through verbal expression when the teacher asks counter questions or questions to check-up or to challenge the student's actions. The results of this study will be beneficial to propel further research about teaching in relation to students' reasoning in design.

Keywords: Technology Education, Design process, Reasoning, Teacher interventions, Teacher-student interaction

1. INTRODUCTION

Students practicing and learning to reason about technology, would ideally be an ingredient in technology education. Ankiewicz et al. (2001, pp. 190) states that "depending on how technology education is taught, it can either promote the desired thinking skills or be reduced to the craft subject from which it originated". Hence, what technology teachers do in the classrooms and how they arrange learning situations is central to how students develop their reasoning. At the same time, reasoning is a broad concept. However, it is commonly acknowledged as the thought process of posing premises leading to a conclusion (e.g. Harman, 1986). Following this broad view, we can derive that the ability to reason is an integral aspect of technological literacy, as it encompasses maintaining, controlling, and operating in order to draw conclusions and make decisions in relation to technology (Alamäki, 2000; Rossouw et al., 2011). Consequently, recognizing the strong correlation between reasoning and decision making, Kruse (2013) emphasized the significance of incorporating reasoning development into students' technology education.

Moreover, technology education is a vast subject. Yet, at its core is the design process, with regards to content of curricula around the world (Norström, 2016). The design process is usually described as the steps or actions taken to reach a goal by designing (Wikberg-Nilsson et al., 2021). Considering the reasoning in this process is essential and Cramer-Petersen et al. (2019) emphasize that making sense of the reasoning in the process is necessary for comprehending the design practice. Therefore, for the teacher to be able to guide students in their learning in the process, considering the reasoning in the process can be fruitful (Seery et al., 2022). Hence, unpacking the students' reasoning in the design process can support the teachers in guiding their students in the process.

12.1 Aim and Research Question

Considering the students' reasoning in the design process can be deemed important. The teacher and their guidance are at the center of this. However, within technology education research, teacher guidance in relation to students' reasoning has not been investigated to any great extent. Nevertheless, gaining knowledge about this would support further insights in how to develop students' reasoning and learning in the design process. Consequently, the aim of this study has been to contribute to this research by posing the following research question.

12.1.1 Research question

What teacher guidance emerge in teacher-student interactions in relation to students' reasoning in the design process?

13 LITERATURE REVIEW

Within the literature, the teacher's role within the design process is usually described as of a guiding nature (e.g., Goldschmidt et al., 2014; Kimbell & Stables, 2007). In a recent study by Sheoratan et al. (2023), different types of feedback and questions used by teachers to support students in a design process were identified. The inductively identified feedback that was used by the teachers were steering feedback, encouraging feedback, and clarifying feedback. The questions that the teachers used was deductively identified as low-level questions, deep reasoning questions, and generative design questions, using a classification of questions described by Eris (2004).

Extensive research has delved into the reasoning logic employed by designers (e.g., Cramer-Petersen et al., 2019). However, there is limited amount of research on reasoning within the design process in the field of technology education and as reasoning is such a broad concept, the research made within the context of technology education is scattered. Daugherty and Mentzer (2008) found that expert designers frequently utilize analogies, suggesting the need for further investigation into the implications of analogical reasoning in technology education. Similarly, Buckley et al. (2018) have highlighted the significance of inductive reasoning and advocated for its integration into technology education. Thorsteinsson and Olafsson (2016) as well as Autio and Soobik (2017) have examined students' reasoning in technology education with a general approach. There has however not been a focus within these studies on reasoning explicitly connected to the design process in technology education.

14 METHOD

14.1 Data Collection

To be able to interpret and analyze teacher guidance in connection to student’s reasoning, data was collected through observations of lessons in Swedish Secondary School. In total, a set of two different observations of technology lessons were made. The intention was to receive a rich data material containing descriptions from technology teachers and their practice. Consequently, teachers that had experience as technology teachers and that had had the time to develop their practice were selected. To establish such a selection, a subjective selection in combination with a snowball selection was made (Denscombe, 2018). One of the teachers, from now on called Bob, taught a nineth grade class and they were working with developing a ventilation system for a location of the student’s own choice. During the observed lesson, the students had made drawings and were in the process of making physical models. Here, 17 students participated in the observation. The other teacher, from now on called Peter, taught a nineth grade class who were in the middle of drawing their dream house. 14 students participated in this observation. All participants had been provided with information about the study prior to the data collection, and they had all signed a written consent form. Additionally, for the students that were under 15 years old, their legal guardians consented in writing as well. The students that did not want to participate in the observations attended the lessons in adjacent rooms.

As the researcher, I participated in the observations as a complete observer. This meant that I participated in the classroom during the lesson without interacting with the teacher or students (Baker, 2006), except to interact to inform or answer questions about the observation or the research study. Data of the situation and interactions was collected through audio recordings of the teacher through a microphone mounted on the teacher. To fully capture the whole interaction, I also made audio recordings of the students through microphones being placed close to each group of students. In addition to this, data was also recorded through video recordings of the classroom. This was made through two cameras filming from two angels in the classroom. The use of two cameras made it possible to capture gestures, movements and artefacts that are important for the context of the interactions. But it also made it possible to arrange the cameras to avoid filming parts of the classroom and avoid filming students that did not want to participate in the study. The two cameras also provided a backup if the equipment were to malfunction. This turned out to be a necessary backup as one of the cameras stopped filming due to overheating.

14.2 Data Analysis

The audio and video data from the observations were jointly transcribed and the interactions between students and the teacher was divided into teacher interventions (cf. Mortimer & Scott, 2003). A teacher intervention was defined as the moment when teacher and student started to interact, and it ended when one of them left the interaction. Teacher interventions that were deemed to not be relevant to the research question or where the context was difficult to comprehend, were removed from the data set. A total of 29 teacher interventions were then analysed through thematic analysis as described by Braun and Clarke (2006).

In the data, both the teacher's actions and verbal expressions in addition to the students' reasoning was of high interest. Thus, the data was coded both deductively with regards to the students' reasoning, and inductively with regards to the teacher's actions and expressions. A model for reasoning in the design process in technology education described by Hultmark (2022) was used as a theoretical framework for the students' reasoning. The model describes the two reasoning types means-end reasoning and cause-effect reasoning and their relationship within in the design process. Through means-end reasoning the students draw conclusions about means that will realise the desired end. Moreover, they base these conclusions on beliefs about cause and effect relationships that can be formed through cause-effect reasoning. To answer the research question, themes were formed considering both the deductive and inductive coding.

15 RESULTS

When the teacher interventions were analysed, three themes were identified. When interacting with the students the teacher was *giving answers*, *asking questions,* and *showing their reasoning* and the verbal expression of the students' reasoning varied with these interventions.

15.1 Giving Answers

The analysis resulted in three subthemes when the teacher was giving answers to their students' questions: *Counter question*, *vague answer* or through *providing a conclusion*. There is a distinct difference in the explicitness of the student's reasoning connected to the teacher's answers. When the teacher answered or reacted through counter questions, the students' reasoning was verbally expressed. The students' reasoning is then foremost expressed through them stating conclusions in the form of stated actions or beliefs. One example of this is when the student Alex askes the teacher Peter a question (Excerpt A). Alex wonders whether it is actually good with many windows in a house (A1). Instead of answering the question directly, Peter askes a counter question (A4). When answering this counter question, Alex's cause-effect reasoning is expressed when he formulates a belief about the effect of many windows (A5). He also provides the premise that it is because they take up space on the wall. Peter confirms Alex's conclusion, but following Alex's reasoning, he asks a question that broadens the perspective (A6).

Excerpt A.
Counter question

A1.	Alex:	Peter, I have a question for you. Is it actually good with many windows in a house?
A2.	Peter:	Many windows?
A3.	Alex:	Yes
A4.	Peter:	Why would it be bad?
A5.	Alex:	Doesn't it lower the [insulation effect]? You know, they take up space on the wall.
A6.	Peter	Yes, so the insulation effect does definitely get worse. But what do you get with many windows? [Pause] Light!

The teachers could also answer students' question by not giving a direct answer. Instead, the teacher gave a vague answer, where these answers were characterized by the notion of prompting students to decide and reach a conclusion on their own. In Excerpt B, this is prominent when the teacher Bob explicitly says that the student, Maria, should reach a conclusion on their own (B2). In contrast to this, the teacher sometimes answered by providing conclusions. The teacher Peter provides conclusions in Excerpt C (C2, C4), when the student Isabel asks if they should add stairs and draw a ramp or not.

Excerpt B.
Vague answer

B1.	Maria:	Should there be a piece of wood under this one too?
B2.	Bob:	You decide. You are the project manager. Nobody should tell you what to do. What your design looks like is up to you.
B3.	Maria:	Mhm

Excerpt C.
Providing conclusion

C1.	Isabel:	But then I would add stairs?
C2.	Peter:	Yes, it's just one step. If you have 0.3.
C3.	Isabel:	Yes, but if I then had a ramp. Or would I […] Would I build it down?
C4.	Peter:	For the garage, then it's better to bring the garage down to ground level and then you have no foundation.
C5.	Isabel:	So I do this directly? [Points to the drawing]
C6.	Peter	Yes

In the interventions where the teacher provides vague answers or when they provide conclusion, the student's reasoning is not explicitly expressed. In the cases of when the teacher provides vague answers, the students reasoning can be expressed in a later stage depending on the conclusion they reach in the form of actions. When the teacher provides conclusion, the students instead express confirmation or asks follow-up questions.

15.2 Asking Questions

Among the questions that the teacher asked the student in the interventions, the analysis yielded in three different subthemes: questions to *check-up*, to *challenge* student's conclusion or to *confirm* that the student understands what the teacher means in a particular case. In Excerpt D, the teacher Bob can be seen to check-up on the student Kim by asking how it went (D1). Kim's answer shows a conclusion in a cause-effect reasoning (D4). In Excerpt E, the teacher Bob can instead be seen to challenge the student Nina's action to use a small wood piece by questioning her action (E3).

Excerpt D.
Check-up

D1.	Bob:	How did it go for you, Kim? Did it go well? Or so-so?
D2.	Kim:	Yes, I am trying to fix this piece
D3.	Bob:	Okay
D4.	Kim:	But the glue didn't work very well

Excerpt E.
Challenge

E1.	Bob:	Wood piece underneath? [Shows with a wood piece]
E2.	Nina:	It is here [points to the wood piece]
E3.	Bob:	Why do you use that small wood piece?
E4.	Nina:	Because it doesn't need to be lifted up, so it doesn't go up like that. [Shows steep slope with model]. It is quite close.

Both when the teacher asks check-up questions and when they ask challenging questions, the student's reasoning is visible through verbal expression. The student Nina's (Excerpt E) means-end reasoning behind her conclusion is made explicit (E4) through the challenging question asked by the teacher. When the teachers ask questions to confirm, the students' answers are short and affirmative.

15.3 Showing their Reasoning

In the teacher interventions, apart from giving answers and asking questions, the teachers also made interventions where they themselves were showing their own reasoning. This was the case when they were providing support or making corrections without a request by the student. In Excerpt F, the teacher Bob has noticed a need to raise a part of the model a bit more and suggest an action (F1). The student Kim questions the conclusion by means of a question (F2), and the teacher's reasoning becomes explicit when providing premises (F3). This is also evident when, in Excerpt G, the teacher Peter provides support by making parts of his reasoning explicit to the student Nour (G2) who are in the process of writing about her reasoning behind her decisions.

Excerpt F.
Making corrections

F1.	Bob:	How many should you have? You must put two
F2.	Kim:	Two?
F3.	Bob:	Yes, we raise it a bit more
F4.	Kim:	Yes okay, yes but I will do it

Excerpt G.
Providing support

G1.	Nour:	Is it good? Should I write about my choice of windows and stuff too?
G2.	Peter:	Yes, you can do that. The most important thing is the walls. But there are windows on the walls, and since windows are the most poorly insulated part of a wall, you can write about the windows and the impact of choosing energy-efficient windows or not.
G3.	Nour:	Should I link the pages at the bottom?

Within this theme, that the teachers providing support through showing their reasoning or parts of their reasoning is prominent. When this is explicit the students either confirms that they follow the teacher's reasoning and act accordingly or they ask question for the teacher to elaborate more.

16 DISCUSSION

The findings of this study shows that the teacher guided their students through *giving answers*, *asking questions*, and *showing their reasoning*. Within each theme the action or verbal expression of students differed in connection to the teacher's guidance. The results emphasize how teachers withholding direct answers from students through counter questions occurs in connection to the student's reasoning being more explicit through verbal expression. The same occurs when the teacher asks questions to check-up on student work or when challenging an action made by the student. The results also showed that both the students' means-end and cause-effect reasoning were made verbally explicit in connection to the teacher guidance.

These results have implications for technology education. By prompting students to articulate their reasoning, teachers can act upon the content of the reasoning and decide on appropriate support. This is in line with what Cramer-Petersen et al. (2019) emphasizes, that making the reasoning explicit supports understanding of design practice. This is also consistent with the discussion of Seery et al. (2022, pp. 12) and that using the frame of reasoning is useful "to unpack the myriad of observed activity". This implies that framing the students' actions and statements through the frame of reasoning is useful to delve into the intricate nature of the design process, which can serve as a foundation for the teachers to support their students in their design endeavours and learning.

In this study, the focus has been on teacher guidance in isolated teacher-student interactions and to relate this to the students' reasoning. To gain more knowledge about this interplay, further studies covering the whole design process or reoccurring guidance of students is desirable. However, the results of this study provide valuable insights to advance further research on teaching concerning students' reasoning in the design process.

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Different Textbooks in Technology Education: Different Opportunities for Developing Disciplinary Literacy

Charlotte Hurdelbrink, KTH Royal Institute of Technology, hurdel@kth.se
Susanne Engström, KTH Royal Institute of Technology, sengstro@kth.se

ABSTRACT

This study aims to investigate textbooks in technology education and what characterizes the content related to how instructional materials in technology for grades 7-9 (ages 13-16) provide students with opportunities to develop disciplinary literacy in the subject of technology - how and to what extent. A delimitation is made to the specific content that covers industrial processes, which according to the curriculum should be taught to students aged 13-16 in the Swedish school. Textbooks constitute an important basis for education, and the study analyses the section that deals with industrial processes in four different technology textbooks commonly used for students aged 13-16. The content of texts has been interpreted in relation to (1) which language development aspects are addressed, (2) which concepts and terms are discussed, and (3) which knowledge students bring with them to upper secondary school through these textbooks. The study investigates the disciplinary specific words, may be unfamiliar to students and how they are explained and described. An important aim is to analyse the opportunities for developing disciplinary literacy provided and whether the examples provided contribute to students' understanding of the subject and to their ability to communicate their understanding of the subject. The preliminary results show differences in what characterizes the content of the books. The preliminary results also show differences regarding the conditions for developing disciplinary literacy.

Keywords: Technology education, Subject literacy, Textbooks, Secondary school, Language development

1. INTRODUCTION

Regarding the subject of technology, students should be able to describe, explain, and reason to demonstrate various aspects such as breadth and depth, how they base their arguments on facts or personal experiences and how they perceive function and usefulness (Skolverket, 2022). Well-functioning textbooks are considered a key factor for students' academic performance (Oates, 2014; SOU, 2021). Each textbook contains pedagogical and didactic ideas, and the design of the texts represents both a selection and an organization of knowledge (Lindensjö & Lundgren, 2000). Students need to read both extensively and varied texts (Stanovich, 2000) and a textbook helps teachers organize their teaching (Oates, 2014; Lambert, 1999; Juhlin Svensson, 2000). Textbooks are also useful when students prepare for exams (Englund, 2006). Teachers in science and technology subjects appear to use textbooks to a great extent (Bachman, 2005). For teachers who are uncertain about their subject knowledge, the textbook can provide support (Driscoll et al., 1994; Englund, 2006), what is likely the case for many technology teachers in Sweden.

Researchers have found, among other things, that many textbooks lack incentives for reflective thinking (Hoff, 2000). The language of the text is fundamental to how students can understand the text (Reichenbergs, 2000), why it is important that examples demonstrating processes, concepts and terms are not overly complex, the language needs to be precise, but not too complicated (Guzzetti et al., 1995). Certain books have fact boxes and other types of text boxes that, despite looking appealing and interesting, create confusion for the student (Budiansky, 2002). If students can connect their own thoughts to the content in the book, comprehension increases (Ornstein, 1994). Similarly, the tasks in the book need to be perceived as relevant to the students (Kirk et al., 2001), they need to be about something they recognize (Roseman, Kulm & Shuttleworth, 2001). Analogue textbooks often function as reference books for students (Driscoll et al., 1994). However, the number of facts can be a problem (Nelson, 2001) as the number of concepts can be too many (Groves, 1995), making it difficult for students to develop an understanding of them (Nelson, 2001). Overall, the texts, images, tables, etc. in the books can present challenges for students (Bowen & Roth, 2002; Stylianidou, Ormerod & Ogborn, 2002; Peacock & Cleghorn, 2004).

18 AIM AND RESEARCH QUESTIONS OF THE STUDY

Within technology education in Sweden, students should be given the opportunity to "develop knowledge about technological solutions and how the components interact to achieve purpose and function" (Skolverket, 2022). This study aims to investigate analogue textbooks in technology education and what characterizes the content related to how instructional materials in technology for grades 7-9 (ages 13-16) provide students with opportunities to develop disciplinary literacy[7] in the subject of technology - how and to what extent. In this project, we have chosen to focus on the central content of the lower secondary level under the area of Technological Solutions: "Processing raw materials into finished products and handling waste in an industrial process, such as in the manufacturing of food and packaging" (Skolverket, 2022). We refer to this content as industrial processes.

The research questions are as follows: What characterizes the content of analogue technology textbooks regarding industrial processes with a focus on disciplinary literacy?

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[7] In this study, we have decided to use the English term "disciplinary literacy" for the Swedish *ämneslitteracitet*.

19 THE THEORETICAL FRAMEWORK FOR THE STUDY

Disciplinary reading involves engaging with the texts one reads within a subject (Shanahan & Shanahan, 2012, 2020). Having insight into the subject's (disciplinary) literacy entails understanding the specific knowledge and skills possessed by those who create, communicate, and use knowledge within that discipline or subject. Within the discipline or subject, there are specific purposes, genres, symbolic artifacts, communication traditions, different quality standards, and language usage (Shanahan & Shanahan, 2012). School textbooks in various subjects are an important part of developing literacy, they provide a picture of the disciplinary literacy (Piper et al., 2018)

To examine the literacy of different technology textbooks, our analysis interprets text structures and linguistic structures. We have interpreted what each book offers students in terms of disciplinary literacy within technology. For our analysis and subsequent discussion, we have also chosen a functional perspective within a didactic analysis of the textbooks (described by Ammert, 2011a), focusing on the content of the book and the perspectives it conveys to the students (Ibid, p. 35), as well as how the content can be received by the students and which knowledge and skills can be stimulated through the book (Ibid, p. 37). We examine the texts, headings, fact boxes, images and tasks of the textbooks, as well as the structure of the text and content. We have been inspired by the analysis model described by Ammert (2011b), through which different types of presentations can be interpreted. According to Ammert (2011b, p. 260), content can be presented and conveyed in different ways, which affects how the reader interprets it. The presentation types described in the analysis model are: stating (reporting, affirmation, facts), explaining (explanation, description, background, consequence), reflecting/analyzing (connection to the reader, experiences or prior knowledge, parallel contexts, concepts and terms, or models).

20 METODOLOGY

The purpose is to examine the texts, headings, fact boxes, concept summaries, pictures and figures of the technology textbooks, and ultimately discuss how students can comprehend what is written and presented in the books. The aim is to identify patterns in the literacy of each textbook, to see if they differ and what they have in common. We want to study the characteristics that emerge in each book and what they offer to the students who read them. We discuss, among other things, the presentation types offered by each book and what they do not offer. The purpose is to describe how the content is presented in each book and the depth of explanation provided.

Four commonly used technology textbooks for middle school students (ages 13-16) were selected. In each book, we focused on the pages that dealt with industrial processes: Book 1 (20 pages), Book 2 (35 pages), Book 3 (34 pages), and Book 4 (14 pages). Text, headings, fact boxes, concept summaries, pictures and figures serve as analysis units.

Using the model described above, we can analyse and discuss how the main text of the textbook presents the content. A stating presentation type asserts and confirms something without explaining or connecting it to contexts. An explaining type provides explanations, while a reflecting/analysing type sheds light on the content from different perspectives (Ammert, 2011b).

For images and figures, we examine their purposes, whether they are illustrative, and if they clarify the text. Regarding concepts and terms,[8] we investigate their purposes, quantity, explanation in the running text, explanation alongside the text, and suggested practice. For tasks, we examine if they serve as diagnostics, focus on concepts, assess understanding, require explanation/description, or involve analysis/reflection. The introduction is analysed in terms of goals, what students will learn, and the section's topic. Headings are analysed for language/concepts familiar to students and inclusion of new terms.

21 RESULTS

21.1 Book 1

The chapter begins with a short introduction that introduces the topic and provides a brief historical overview of a technical solution. Early in the chapter, there is a bullet-point summary of what students will learn in this chapter. The narrative voice directly addresses the reader using the pronoun "you"[9]. The initial headings are formulated in a way that allows students to recognize and understand the concepts and terms used. An example of such a heading is "How baby formula and porridge are made." In sections where different technical solutions are presented, new concepts and terms are explained in the headings themselves, such as the term "evaporation": "Evaporation - heating to remove water."

The main text is explanatory/descriptive in nature, but it also includes comments from conversations with individuals knowledgeable about the production processes. These individuals describe parts of the various processes. The text sections offer varied language and structure. The reader is partially included through the use of the pronoun "we". At the beginning of the chapter, a map of concepts and terms is presented, featuring a total of 21 concepts and terms, some of which are commonly known such as "milk," "grazing cows," and "packaging." The concepts and terms are not emphasized in any way within or in connection to the text, apart from the map of concepts and terms, except for the following four: skim milk, evaporation, spray drying, and roller drying. At the end of the chapter, it is possible to practice eight out of the 21 concepts and terms mentioned in the initial map.

The chapter primarily contains illustrative photographs, which sometimes clarify the text. Most of the photographs can be interpreted by students as they show relatively familiar situations and environments, such as a man feeding a baby with a bottle or cows in a field. Other photographs, such as those depicting historical or factory environments, may require an explanation. There are also photographs of purely illustrative nature.

The chapter concludes with a bullet-point summary followed by a spread called "The Finale," where students can practice a selection of the concepts and terms mentioned at the beginning of

[8] In the Swedish school context, *ord* (words) and *begrepp* (concepts) are used or only *begrepp* without distinguishing between concepts and terms. We have chosen here to consistently use concepts and terms without distinguishing between what are concepts and what are terms.
[9] second person singular pronoun, in Swedish *du.*

the chapter, explain different parts of the technical solutions and problems. There are also instructions for two mini-projects.

21.2 Book 2

The chapter begins with a short introduction to the section on technical systems, with a focus on process industries that use various technical systems, using a paper mill as an example. Early in each section, there is a bullet-point summary of what students will learn in this chapter under the heading "goals." The narrative voice directly addresses the reader using the pronoun "you"[10] Some headings contain new concepts and terms, such as *process industries* and *bottleneck*, which are explained in the following text section. Other headings provide an explanation for new concepts and terms. When presenting technical systems, all headings follow the same structure, for example, "xxx as a technical system."

The main text is predominantly explanatory/descriptive, but there are sections of a more reflective/analytical nature. These sections, for example, place a question or aspect in a larger perspective, such as the global. The text consists mainly of relatively short main clauses where the reader is directly addressed using "you". The reader is also included through the use of "we" in the text. The sections describing technical systems follow the same disposition and structure.

At the beginning of each section, a number of concepts are presented. A total of 18 concepts and terms are presented. These concepts and terms are highlighted in the text where they are also explained. A smaller selection of concepts and terms is continuously emphasized and practiced, such as “standard time” and “standardization”.[11]

The chapter includes illustrative photographs, some of which also clarify the text. These photographs have descriptive captions to clarify the connection to the text. Other photographs are inherently interpretable, such as a photograph of a ball of yarn or a milk carton, but their purpose can mainly be seen as illustrating the theme of the text. The highlighted technical processes are described with a relatively short text, which is also explained through a series of images illustrating the different steps in the processes with a consistent structure.

Students are continuously given the opportunity to practice concepts and terms, describe, explain, or provide examples of what they have just read through one or a few questions on each page the next to the main text. Each section concludes with a number of tasks where students have the opportunity to explain, describe, and reason about what is presented in the chapter. Each section ends with a project (create a model of a process industry or program a robot).

21.3 Book 3

The chapter begins with a box that presents the focus in bullet points. Each section begins, after a short introduction, with a bullet list of what the specific section will cover, along with a list of

[10] In Swedish: du.
[11] In Swedish: *normaltid* and *standardisering*.

the highlighted concepts and terms. In the introductory section on early technical processes, most of the headings contain familiar concepts and terms for most students such as "Manufacturing in the Stone Age"/"We become farmers - and specialised" [12] In later sections, which cover technical processes in today's society, the headings consist of new concepts and terms that are explained in the subsequent text. An example of such a term is "automatic processes". The main text is predominantly explanatory/descriptive. However, the texts in the introductory section on technical processes in a historical perspective are more reflective/analytical, while the concluding and in-depth pages, called "Plus pages," have a more assertive character. The language of the text includes shorter main clauses as well as more elaborated phrases. The text does not directly address the reader, nor does it include the reader. Instead, the impersonal pronoun "one"[13] or other impersonal formulations are used.

Concepts and terms are presented early in each section, and a total of 28 concepts and terms are highlighted. In addition to these concepts and terms, there is a second level of concepts and terms that are highlighted in connection with the descriptions of the different processes. Those mentioned at the beginning of each section are marked in italics in the text and explained in the running text. Students can practice a number of concepts and terms at the end of each section. These concepts and terms do not always correspond to those highlighted at the beginning of the section. The exercises vary and can, for example, consist of a fill-in-the-blank text, a crossword puzzle, or an exercise where concepts, terms and appropriate descriptions are matched.

Few of the photographs included in the chapter, are purely illustrative in nature. An example of a purely illustrative photograph shows a woman and a man at a conveyor belt in a food industry. The photograph lacks a caption. Most photographs are complemented by a caption, thus providing additional information and clarification of the main text. The captions make the photographs that are not self-explanatory understandable to students. In addition to photographs, there are a few schematic sketches of the different steps in the described processes. The sketches require reading and understanding the text. These schematic sketches include concepts and terms that are not highlighted at the beginning of the section.

Each section concludes with a "Can you?" box, where students have the opportunity to describe, explain, and talk about what has been presented. The content of the chapter is summarized in in a concise manner on a page towards the end of the chapter. At the end, there are also "Plus pages" that delve into several aspects of what has been discussed in the chapter. Finally, there is a page with review questions, exercises to describe, analyze, evaluate facts explain concepts and terms as well as practical tasks related to the content.

21.4 Book 4

The chapter begins with four rhetorical reflection questions such as "How were objects made in the past?" and "What are the consequences of today's factory production?"[14] that also serve as

[12] Tillverkning på stenåldern/Vi blir bönder - och specialiserade
[13] In Swedish "man".
[14] In Swedish: "Hur tillverkades föremål förr i tiden?" and "Vilka konsekvenser medför dagens fabrikstillverkning?"

an introduction to the chapter. After these initial rhetorical questions, the chapter begins directly. The headings are short and alternately formulated with language familiar to the students and alternately so that new concepts and terms constitute the entire heading.

The main text is predominantly explanatory/descriptive, but the section on sustainable development has a more reflective/analytical character. The text consists of longer main clauses and more elaborate phrases. When a process is described and explained, the reader is often addressed directly using "you"[15] and the reader is included in the steps of the process through formulations with "we." In other sections, the impersonal pronoun "one"[16] is used.

22 concepts and terms are introduced in the text by marking them in bold. In some cases, the explanations of them are supplemented by a sketch of, for example, a sensor or an actuator. Students are given limited opportunities to practice their understanding of concepts and terms using the textbook in the "test yourself" sections following each section.

The purpose of the majority of the photographs in the chapter is to clarify the text. The description of what the photographs depict is provided by an explanatory caption, which in most cases makes them interpretable for the students. However, despite the caption, some of the images might be difficult for students to interpret due to the chosen angle or cropping of the photograph. One photograph, a toothbrush, is purely illustrative. In addition to photographs, there are schematic sketches of the different steps in the processes and various forms of control, such as pneumatic and hydraulic, in the in-depth section called "Learn More."

After each section, there is a box with questions where students can test their understanding of a few of the highlighted concepts and terms, and the meanings of different parts of the processes and how they work. There are also questions for explanation and reasoning. At the end of the chapter, there is a page with questions to ponder and tasks related to programming a robot. Finally, there is a brief summary of the content.

22 DISCUSSION

Disciplinary specific language involves relevant content area specific concepts and terms, and the specific linguistic characteristics that are characteristic of each school subject. For a student to develop disciplinary specific language and thus develop critical thinking, the student must also encounter a language that, on the one hand, allows them to understand and absorb the subject matter and, on the other hand, allows them to encounter a language that enables them to develop their own language.

In the four textbooks the authors have chosen different ways to capture students' interest. An important factor in capturing students' interest early on is that they are initially presented with language that they understand and can relate to without immediately encountering words and concepts whose meaning they do not understand or cannot relate to. The authors have chosen

[15] In Swedish “du”.
[16] In Swedish “man”.

different strategies for this. In one book, both the content and illustrations are chosen to be recognizable to many children: the production of food for young children is illustrated with a baby being fed by a man and cows in a meadow. The text is explanatory/narrative with varied language, while moving in environments familiar to many students, and the headings are formulated in a way that allows students to imagine the content of the upcoming text. In another, the chapter begins with early technical processes starting from the Stone Age and ending in mass production in the textile industry of the 20th century. The text in this section has a reflective/analytical character. The headings give an idea of the content of the subsequent text, and many of the descriptions are illustrated through interpretable photographs for the students. In a third book, the students are immediately introduced to an unfamiliar factory environment, while a narrator's voice directly addresses the reader and includes them in the processes being described. The headings here are short and provide limited understanding of the content of the text that follows.

The textbooks are illustrated with carefully selected photographs and sketches. A few photographs are purely illustrative, while the majority aim to clarify the processes being described. The photographs also serve another purpose - to make the textbooks appealing and engaging. In the work on Book 4, it can be assumed that emphasis was placed on making the photographs captivating, although in some cases, it simultaneously complicates the interpretation of the image, as the chosen angle might make it difficult to see what the image is showing even when a descriptive caption is provided.

Concepts and terms constitute an important part of students' development of disciplinary specific language. Highlighting and explaining new disciplinary specific concepts and terms while giving students the opportunity to practice them and place them in a relevant context are important elements. In three of the four textbooks, new concepts and terms are introduced at the beginning of the chapter. Reading and understanding the concepts and the terms is an important part of learning, but it is equally important to actively use them. In three of the books, there are elements where students have the opportunity to work on learning the concepts and terms. Most often, this involves students being able to explain a selection of the concepts and terms that are introduced. Book 3 exhibits the greatest variety of exercises om concepts and terms, while those introduced at the beginning do not always correspond to the concepts and terms that students are expected to practice.

Each chapter or section concludes with a practice/diagnostic section consisting of comprehension questions and tasks where students practice explaining or describing facts. In three of the books, there are also tasks where students are asked to reflect and/or analyze the problems. In all textbooks, students are given the opportunity to try out such processes described, albeit on a smaller scale.

The textbooks demonstrate a wide range of examples and descriptions within the framework of the same theme. Consequently, this leads to significant variations in students' knowledge and understanding of the theme, both in terms of concrete knowledge about processes and the ability to explain and describe industry processes using the concepts and terms found in different teaching materials. One potential consequence of this is that students may progress to high school with highly diverse technology knowledge. At the same time, this places significant demands on primary school teachers who may need to compensate for aspects that the textbooks may not provide opportunities to practice. It also poses challenges for high school teachers who may encounter new students with substantial differences in their level of knowledge.

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Social Emotional Learning and its Framework for Technology Education

Virginia R. Jones, Old Dominion University, vrjones@odu.edu
Daniel L. Trent, Bluefield State University, dtrent@bluefieldstate.edu

ABSTRACT

Social Emotional Learning (SEL) is a key construct for engagement in technology education learning at the undergraduate level. The sample population for this applied research study is two higher education institutions, one located in the Mississippi Delta with a predominately homogenous population of rural, African American students and the other in West Virginia, with a predominant population of rural Caucasian students. The students were enrolled in technology education-based courses and participated in the research study survey to assess their social emotional learning and their overall college success and engagement. The findings of this very limited sample size showed that undergraduate students failed to connect the importance of social emotional skills especially empathy and social awareness with academic success. Students tended to rank themselves highly in academic based categories even when their academic GPA did not reflect that rigor. All students ranked themselves low in awareness of others' emotions and especially awareness of their faculty's perspectives.

Keywords: diversity, social emotional learning, engagement, self-efficacy

1. INTRODUCTION

This study reviewed the social emotional learning aptitudes of early college students, defined as undergraduates, at two diverse U.S. higher learning universities located in different geographical regions of the United States. The purpose of the research study was to determine if a high level of social emotional learning skills was consistent with a higher overall academic GPA as supported by numerous research studies and literature (CASEL, n.d.; OECD, 2021; Panorama, n.d.). The research problem was: Did early college students equate their social emotional skills with their academic achievement in college? The research questions were:

- RQ1: Is there a relationship between students' SEL self-reports and their university academic standing?
- RQ2: Do students accurately assess their SEL levels when self-reporting?

The first university, identified as a Historically Black University (HBCU) is in the state of Mississippi, in the southern part of the United States, and the second university is in West

Virginia, still geographically considered a southern state, and is classified as an HBCU but is one of the few in this classification that is a predominately white institution (PWI). The students from both universities were enrolled in technology education-based courses during the spring 2023 semester and participated in the research survey pertaining to Social emotional learning (SEL).

This study focused on technology education-based classes to address and contribute to SEL development for future learning and success. Students were administered the survey to self-assess their SEL skills. Data was obtained from each respective institute for students' cumulative grade point average (GPA). The researchers analysed the self-assessment scores and the students' GPAs to determine if there is a relationship between their self-assessment and academic success. Research showed that 67% of the abilities needed for successful STEM and technology education learning are based on the learners' emotional learning levels (SEL). This study presents research on two HBCU undergraduate cohorts to examine their SEL levels compared to their current academic grade point average. The focus areas in this study's student survey included the following five core social emotional learning competencies:

(i) self-awareness – recognizing emotions, strengths, and limitations.
(ii) self-management - regulating emotions, thoughts, and behaviours.
(iii) social awareness – understanding and empathising with others.
(iv) relationship skills – developing and maintaining relationships, communication, cooperation, and conflict resolution.
(v) responsible decision making – constructive choices based on ethical considerations, social norms, and personal values (SSIS CoLab, 2020).

Social and emotional skills are ones' abilities to regulate thoughts, emotions, and behaviour. These skills help one adjust to their environment and form the patterns one uses in all human activities especially in learning new tasks whether in formal or informal settings (OECD, n.d.; Darling-Hammond, et al, 2020). Research about social-affective neuroscience study of the brain supported that the DMN (default mode network) is key to engagement concerning task orientation such as persistence in classroom exercises as well as providing a personal relevance for the learner (Immordino-Yang, 2016). She further postulates that "students' achievement depends on social-emotional factors and executive control…and which aspect of their identity is salient to them in the current social-emotional context" (p. 212). The researchers believe a strong SEL attachment to the learning process promotes the use of this DMN network. SEL based learning supports technology education where students experience hands-on learning with a focus on reflections on personal learning, relevance to their circumstances, and achievement (Immordino-Yang, 2016). Prioritizing SEL while learners are beginning their post-secondary education requires an investment in crucial educational learning opportunities for under-represented populations. These skills are promulgated by the Standards for Technological and Engineering Literacy (STEL) in their practices for employing technology education successfully in different contexts (ITEEA, 2020). Research upheld that a high level of SEL skills is required in technology education particularly skills such as "remaining calm, flexible and realistic" when dealing with classroom pressure (Yekinni & Ogbuanya, 2022, p. 12). Yekinni and Ogbuanya (2022) further assert that having high EL skills has a "positive relationship with teamwork, skills, team harmony, effectiveness and performance" for the student (p. 13). Grubbs et al., (2018) stress that engineering habits of mind, habits students should develop, include many SEL skills such as communication, creativity, collaboration, and ethical considerations.

Engagement of all learners requires an emotional connection to the content and brain research supports emotions that are consistent across all cultures supporting the need for educators to encourage SEL learning as a methodology to provide the learners with content that reflects their lived experience.

Social and emotional skills are shaped by many facets of one's life such as families, peers, educational settings, life events, and individual actions (OECD, 2021). Further the data from the OECD survey (2021) supports that "age, gender, socio-economic status and migration background" are fundamental to development of strong SEL skills (p. 44). Social emotional skill development is consistent with the contemporary knowledge of social and emotional skills as characteristics and abilities that are changeable and react, either growing or decreasing, along with the person's biological and psychological changes, influences from the environment around the person. OECD's data, based on primary and secondary school students, is transferrable to early college study as it promoted that SEL skills are a strong predictor for school performance. These indicators are data driven and indicate that students with similar socio-economic backgrounds have different post-secondary education expectations, and that SEL skills are linked to students' career aspirations (OECD, 2021). The research further posited that across data points from participating cities, "the proportion of students who held high expectations for further education was related to how they portrayed their own social and emotional skills (OCED, p. 74). The BTAE (Better than average effect) theory is a strong consideration in this research as it supports that self-ranking has inherent bias of self-enhancement especially in social comparisons (Brown, 2012).

Floricica and Mihai's research (2020) also asserts non-cognitive abilities show a positive correlation to personality traits. The research also states personality traits are a combination of emotional, motivational, and cognitive skills in humans. Considering the tie between SEL, academic, and well-being, there is an urgent obligation to promote *deeper learning* which consists of collaborative, communal activities. This deeper learning develops transferable knowledge for the learner allowing them to understand the learning domain as well as how, why, and when in applying the knowledge. This product of deeper learning is a blend of knowledge (cognitive, academic) and skills (social emotional learning) to produce *21st century competencies'* (National Research Council, 2012).

Literature also asserted that one obstacle in evaluating and comparing SEL skills and their resultant comparisons on the cognitive proficiencies and economic outcomes (workforce attainment in life) is the sparsity of standardized instruments that are validated and reliable to measure these noncognitive aptitudes. As in this study, most noncognitive proficiencies are measured by ranking or rating schemes rather than a test instrument. Most surveys that rank these abilities are either self-rated or by observation such as by teachers or others in the educational setting (National Research Council, 2012). According to research, the European Commission has begun investigating how to best assess how noncognitive abilities and personality traits commingle with workplace success (Brunello & Schlotter, 2011).

24 METHODOLOGY

The researchers used a publicly available free survey from Panorama education. Although the survey was specifically designed for learners in grades 3-5 and grades 6-12, the researchers felt the questions were still applicable to undergraduate students and would provide a strong measure of their SEL while starting their higher education journey. The survey measured student competencies specifically in the areas enumerated below:

(i) Grit
(ii) Growth mindset
(iii) Self-management
(iv) Social Awareness
(v) Self-efficacy
(vi) Learning Strategies
(vii) Classroom effort
(viii) Social Perspective-taking
(ix) Self-efficacy about specific subjects
(x) Emotion regulation (Panorama, n.d. p. 6)

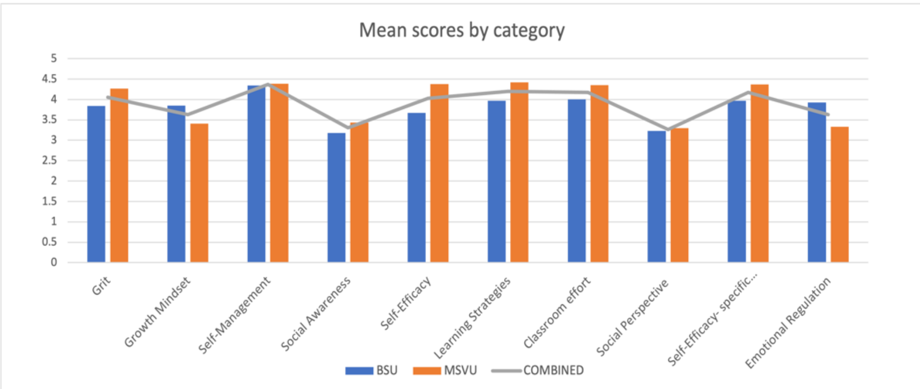
Students were given the survey in their Computer Aided Manufacturing and Machine Elements II classes at Bluefield State University (BSU) and in their Computer Aided Drafting and Design (CADD) Applications II and Introduction to Architecture classes at Mississippi Valley State University (MSVU). Fifteen students from Bluefield State participated, of which 12 were male and three were female. Nine students from Mississippi Valley State participated in the survey of which seven were male and two were female.

The instrument used was the Panorama Social-Emotional Learning Survey, specifically the student competencies survey (Panorama, n.d.). The Grit section contained five questions and were ranked on a Likert scale of 1 – almost never to 5 – almost always, extremely focused, or a variation. The Growth mindset section contained six items asking about the ability to change the items. The rankings were a Likert scale of 1 – not at all possible to change to 5 – completely possible to change. The Self-management section asked *During the past 30 days…* with 10 statements ranked from 1 – almost never to 5 – almost all the time. Social awareness also asked *During the past 30 days…* with eight statements ranked from 1 – not carefully at all, did not care at all, did not get along at all, not all clearly, not at all respectful, not at all to 5 – extremely carefully, cared a tremendous amount, almost all the time, got along extremely well, extremely clearly, and tremendous amount. Self-efficacy section had five questions with Likert scale rankings from 1 – not at all confident to 5 – extremely confident. Learning strategies section contained five questions with rankings from 1 – not at all likely, not at all confident, almost never, not well at all, almost never to 5 – extremely likely, extremely confident, almost always, and extremely well. The next section on classroom effort contained five questions with responses ranked from 1 – almost no effort to 5 – a great deal of effort. The next section was Social Perspective-taking with six questions ranked from 1- not hard at all, almost no effort, not at all, not hard at all to 5- extremely hard, a tremendous amount of effort, extremely hard. An additional self-efficacy section was utilized asking self-efficacy about their specific technology and engineering education courses. There were six questions ranked from 1 – not at all confident to 5 – extremely confident. The section on emotion regulation contained six questions with response ranking from 1- not easily at all to 5 – extremely easily. The survey is attached in Appendix A.

25 RESULTS

The overall Grade Point Average (GPA) for students from Bluefield State University was 3.39 while the overall GPA for Mississippi Valley State University students was 3.20. The average grade for the technology education course in which the students were enrolled, based on a 4-point scale, was 3.40 for BSU and 2.89 for MVSU. Overall mean scores for each of the ten categories reported were computed for each school and a combined average was calculated.

Figure 1
Overall mean scores for each category and combined average



MVSU students scored themselves highest in learning strategies (4.42) indicating they believe they used deliberate actions to manage their learning process. They also reported scores over 4.0 on a 5-point scale for grit (4.27 revealing they felt they were able to persevere through setbacks to achieve their educational goals, self-management (4.39) controlling their emotions, thoughts and behaviors in various situations, self-efficacy (4.38), classroom effort (4.35) showed they felt the effort was quite a bit for their academics, and self-efficacy about specific subjects (4.37) implying they felt they could succeed in the technology education courses. A lower rating for a growth mindset (3.41) indicated students believed they had no ability to change factors crucial to their educational performance. Interestingly, the students rated themselves low on social awareness (3.43) denoting a lack of connection with others and their perspectives (a lack of empathy). Concurrently, they rated themselves low on social perspective taking (3.30) again signifying a lack of an empathetic connection with the teacher's (professor) and the classroom environment. Not surprisingly, the students rated 3.33 on emotional regulation indicative of an undeveloped system of understanding how to adjust and control their emotions.

BSU students scored themselves highest in self-management (4.34). They rated themselves at a 4.00 score for effort. The remaining categories were below the score of 4.00 with grit (3.84), self-efficacy about specific subjects (3.93), growth mindset (3.85) learning strategies (3.97), and emotional regulation (3.93) are just below the 4.0 mark. This is significant as one student did not answer all questions which skewed the final overall averages on these categories. For BSU, the students ranked themselves lowest on social awareness (3.18) and social perspective taking (3.22) scoring which is consistent with undeveloped social emotional skills (empathy) but ranked higher on emotional regulation (3.93) denoting an awareness of other's emotions and perspectives.

BSU students self-reported lower scores than MVSU students in every category except growth mindset (BSU = 3.85, MVSU = 3.41). This is contradictory to the overall grade point averages attained by each group (BSU = 3.39, MVSU = 3.20) and the course grades (BSU = 3.40, MVSU = 2.89).

Students with an overall GPA of 3.50 or higher from each school (BSU had eight students out of 15 [53.30%], MVSU had two students out of nine [22.22%]) reported identical mean scores of 4.10 in the grit category. Three students from each school had overall GPA scores below 3.00. The MVSU students with lower GPAs reported almost the same mean score for grit (4.13) as their higher performing counterparts. The BSU students with lower GPAs reported a mean grit score of 3.40.

26 DISCUSSION

The results indicate students' self-rankings were overstated based on their course and overall grade averages. There is no way to determine the basis for overestimated rankings although it can be hypothesized that some lack the ability to accurately assess their ability to perform academic tasks and succeed in their coursework. It appears from this research that students with lower overall GPA scores have overstated views of their social and emotional skills. It also appears that higher performing students (based on their GPAs) may under report these skills.

These findings, although from a very limited sample, are consistent with literature stating that self-reported Social Emotional learning skills are fraught with inaccuracies and can present false ratings. The results do indicate a strong lack of understanding emotional and social connectiveness needed for academic success. Research has shown students attribute success to their own abilities or intelligence and failure is due to someone or something else outside of their control (Karpen, 2018). Karpen further stated, "weak correlations between self-assessment and performance demonstrate that people misestimate their abilities" (para. 4). Dunning, et al. (2004) asserted that self-assessments are flawed as oneself view is only marginally related to their actual behaviors (social-emotional constructs) and performance. These characteristics are termed the *BTAE* (Better than average effect) and account for the discrepancies in this research versus the actual academic performance of the students.

27 CONCLUSION

The research study sought to determine if a high level of social emotional learning skills was consistent with a higher overall academic GPA as supported by numerous research studies and literature (CASEL, n.d., OECD, 2021, Panorama, n.d.). The research problem was: Did early college students equate their social emotional skills with their academic achievement in college? The research questions were:

- RQ1: Is there a relationship between students' SEL self-reports and their university academic standing?
- RQ2: Do students accurately assess their SEL levels when self-reporting?

The survey data showed early college students' self-assessment for social and emotional learning was skewed with either over confidence in a SEL ability or under-estimating their ability on SEL survey. Due to the small sample sizes, 15 and nine students from each university's technology education courses, the researchers were unable to perform any statistical measures to determine if there is a correlation between students social emotional learning skills and their overall college GPA.

This survey data will assist educators in understanding the link between SEL and academic performance, as well as students increased social competence. It is vital that all involved in education understand the importance of SEL to foster students' holistic development. The instrument used was developed for upper-level secondary students and in this study ranked by undergraduates in higher education which may account for their overzealous assessments of their social skills. The study should be repeated using a more tailored instrument and a larger sample size.

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29 APPENDIX A

29.1 Item A

Student Competencies

Grit — *Recommended*
How well students are able to persevere through setbacks to achieve important long-term goals.

Question	Response Options				
How often do you stay focused on the same goal for several months at a time?	Almost never	Once in a while	Sometimes	Frequently	Almost always
If you fail to reach an important goal, how likely are you to try again?	Not at all likely	Slightly likely	Somewhat likely	Quite likely	Extremely likely
When you are working on a project that matters a lot to you, how focused can you stay when there are lots of distractions?	Not at all focused	Slightly focused	Somewhat focused	Quite focused	Extremely focused
If you have a problem while working towards an important goal, how well can you keep working?	Not well at all	Slightly well	Somewhat well	Quite well	Extremely well
Some people pursue some of their goals for a long time, and others change their goals frequently. Over the next several years, how likely are you to continue to pursue one of your current goals?	Not at all likely	Slightly likely	Somewhat likely	Quite likely	Extremely likely

29.2 Item B

Growth Mindset — *Recommended*
Student perceptions of whether they have the potential to change those factors that are central to their performance in school.

Question	Response Options				
Whether a person does well or poorly in school may depend on a lot of different things. You may feel that some of these things are easier for you to change than others. In school, how possible is it for you to change:					
Being talented	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change
Liking the subjects you are studying	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change
Your level of intelligence	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change
Putting forth a lot of effort	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change
Behaving well in class	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change
How easily you give up	Not at all possible to change	A little possible to change	Somewhat possible to change	Quite possible to change	Completely possible to change

29.3 Item C

Self-Management — *Recommended*
How well students manage their emotions, thoughts, and behaviors in different situations.

Question	Response Options				
During the past 30 days...					
How often did you come to class prepared?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you follow directions in class?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you get your work done right away, instead of waiting until the last minute?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you pay attention and resist distractions?	Almost never	Once in a while	Sometimes	Often	Almost all the time
When you were working independently, how often did you stay focused?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you remain calm, even when someone was bothering you or saying bad things?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you allow others to speak without interruption?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often were you polite to adults?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often were you polite to other students?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How often did you keep your temper in check?	Almost never	Once in a while	Sometimes	Often	Almost all the time

29.4 Item D

Social Awareness — *Recommended*

How well students consider the perspectives of others and empathize with them.

Question	Response Options				
During the past 30 days...					
How carefully did you listen to other people's points of view?	Not carefully at all	Slightly carefully	Somewhat carefully	Quite carefully	Extremely carefully
How much did you care about other people's feelings?	Did not care at all	Cared a little bit	Cared somewhat	Cared quite a bit	Cared a tremendous amount
How often did you compliment others' accomplishments?	Almost never	Once in a while	Sometimes	Often	Almost all the time
How well did you get along with students who are different from you?	Did not get along at all	Got along a little bit	Got along somewhat	Got along pretty well	Got along extremely well
How clearly were you able to describe your feelings?	Not at all clearly	Slightly clearly	Somewhat clearly	Quite clearly	Extremely clearly
When others disagreed with you, how respectful were you of their views?	Not at all respectful	Slightly respectful	Somewhat respectful	Quite respectful	Extremely respectful
To what extent were you able to stand up for yourself without putting others down?	Not at all	A little bit	Somewhat	Quite a bit	A tremendous amount
To what extent were you able to disagree with others without starting an argument?	Not at all	A little bit	Somewhat	Quite a bit	A tremendous amount

29.5 Item E

Self-Efficacy — *Recommended*

How much students believe they can succeed in achieving academic outcomes.

Question	Response Options				
How confident are you that you can complete all the work that is assigned in your classes?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
When complicated ideas are presented in class, how confident are you that you can understand them?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
How confident are you that you can learn all the material presented in your classes?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
How confident are you that you can do the hardest work that is assigned in your classes?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
How confident are you that you will remember what you learned in your current classes, next year?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident

29.6 Item F

Learning Strategies — *Supplemental*

How well students deliberately use strategies to manage their own learning processes generally.

Question	Response Options				
When you get stuck while learning something new, how likely are you to try a different strategy?	Not at all likely	Slightly likely	Somewhat likely	Quite likely	Extremely likely
How confident are you that you can choose an effective strategy to get your schoolwork done well?	Not at all confident	Slightly confident	Somewhat confident	Quite confident	Extremely confident
Before you start on a challenging project, how often do you think about the best way to approach the project?	Almost never	Once in a while	Sometimes	Frequently	Almost always
Overall, how well do your learning strategies help you learn more effectively?	Not well at all	Slightly well	Somewhat well	Quite well	Extremely well
How often do you use strategies to learn more effectively?	Almost never	Once in a while	Sometimes	Frequently	Almost always

29.7 Item G

Classroom Effort — *Supplemental*

How much effort students put into school and learning.

Question	Response Options				
How much effort do you put into getting involved in discussions during class?	Almost no effort	A little bit of effort	Some effort	Quite a bit of effort	A great deal of effort
When your teacher is speaking, how much effort do you put into trying to pay attention?	Almost no effort	A little bit of effort	Some effort	Quite a bit of effort	A great deal of effort
How much effort do you put into your homework for this class?	Almost no effort	A little bit of effort	Some effort	Quite a bit of effort	A great deal of effort
Overall, how much effort do you put forth during this class?	Almost no effort	A little bit of effort	Some effort	Quite a bit of effort	A great deal of effort
How much effort do you put into learning all the material for this class?	Almost no effort	A little bit of effort	Some effort	Quite a bit of effort	A great deal of effort

29.8 Item H

Social Perspective-Taking — *Supplemental*

The extent to which students consider the perspectives of their teachers. *Please note that this measure OPTOis only available for students in Grades 6-12.*

Question	Response Options				
How hard do you try to understand your teachers' point of view?	Not hard at all	Slightly hard	Somewhat hard	Quite hard	Extremely hard
During class, how hard do you try to understand what your teachers are feeling?	Not hard at all	Slightly hard	Somewhat hard	Quite hard	Extremely hard
Overall, how much effort do you put into figuring out what your teachers are thinking?	Almost no effort	A small amount of effort	Some effort	Quite a bit of effort	A tremendous amount of effort
How much effort have you put into figuring out what your teachers' goals are?	Almost no effort	A small amount of effort	Some effort	Quite a bit of effort	A tremendous amount of effort
How much do you try to understand your teachers' motivation for doing different classroom activities?	Not at all	A little bit	Somewhat	Quite a bit	A tremendous amount
When your teachers seem to be in a worse mood than usual, how hard do you try to understand the reasons why?	Not hard at all	Slightly hard	Somewhat hard	Quite hard	Extremely hard

29.9 Item I

Emotion Regulation — *Supplemental*

How well students regulate their emotions.

Question	Response Options				
When you are feeling pressured, how easily can you stay in control?	Not easily at all	Slightly easily	Somewhat easily	Quite easily	Extremely easily
How often are you able to pull yourself out of a bad mood?	Almost never	Once in a while	Sometimes	Frequently	Almost always
When everybody around you gets angry, how relaxed can you stay?	Not relaxed at all	Slightly relaxed	Somewhat relaxed	Quite relaxed	Extremely relaxed
How often are you able to control your emotions when you need to?	Almost never	Once in a while	Sometimes	Frequently	Almost always
Once you get upset, how often can you get yourself to relax?	Almost never	Once in a while	Sometimes	Frequently	Almost always
When things go wrong for you, how calm are you able to remain?	Not calm at all	Slightly calm	Somewhat calm	Quite calm	Extremely calm

Preliminary study of how 21st-Century Skills are developed during a participatory user-centred curriculum intervention at Key Stage 3 in Design and Technology

Philip A. Jones, Liverpool John Moores University, p.a.jones@2021.ljmu.ac.uk

ABSTRACT

Whilst designing 'for and with' end-users has been commonplace in the professional design space since the 1970s, there is a lack of research evidence of empathic or human-centred design in primary and secondary education. This paper presents a preliminary study of the 'Solving Genuine Problems for Authentic Users Project' conducted to explore the effect that involving end-users throughout the design process has on students and their outcomes as part of their Key Stage 3 D&T education. Sixteen 12-13-year-old students at a secondary school in England worked in teams of four to with a member of the school catering staff to develop a prototype, aimed towards solving a problem that they identified together. The student researchers utilised agency in the research methods they employed to gain a better understanding of the design context. Data included a pre and post questionnaire to measure students' creative potential which helped to improve an understanding of how empathy, a recognised 21st-century skill, was developed over the course of the study. Other data collected included photographs of student work and the students' field notes. Data was thematically coded to offer a narrative of the findings. This study contributes to the growing understanding of 21st-century skill development in a D&T context, as well as the facilitation of face-to-face collaboration with end-users at an early stage of secondary design and technology education.

Keywords: user-centred design, participatory design, empathy, 21st-century skills, design education

1. INTRODUCTION

21st century life and work require individuals to possess specific skills, often referred to as soft or more recently, human skills, to successfully confront the complex challenges presented by technology and society. So-called 'wicked problems' such as climate change, overpopulation, and rapid technological advancements have emerged, which are complex and 'messy' (Buchanan, 1992; Rittel & Webber, 1973), each demanding a diverse range of skills to navigate successfully. Educators and policymakers around the world are placing a greater emphasis on enabling students to develop so-called 21st-century skills across all phases of education, to ensure that they are equipped to address these challenges (Ananiadou & Magdalean, 2009). With new forms of artificial intelligence (AI) presently in the spotlight, a shift in the labour market paradigm has motivated policymakers to demonstrate an appreciation for students' human capacity for creativity (OECD, 2019a). Focusing on the development of human creativity alongside the proliferation of AI and other technological advancements, encourages people to embrace the human uniqueness of creating value, reconciling tensions, and taking responsibility (OECD, 2019b). The OECD Skills for 2030 initiative (OECD, 2019a; 2019b) centres around the development of competencies related to cognitive and meta-cognitive skills, social and emotional skills, and practical and physical skills. The design and technology (D&T) curriculum in England is well-placed to develop all of these skills in children and young people, especially in the context of addressing contemporary societal challenges (Morrison-Love, 2022) due to its focus on designing within contexts and responding to problems, enabling students to become socially involved and participate in authentic problem-solving; bringing about hope and change through transformation (Klapwijk, 2017; Morrison-Love, 2017). The national picture in England at Key Stage 3 is bleak and has been recognised by the Design and Technology Association as being a problem for the future of the subject. The Association has released a position paper (2023) highlighting the importance of change at Key Stage 3, capitalising on the development of human skills.

An approach to design that has become increasingly popular in industry is participatory design, which engages end-users as active participants in the design process (Sanders & Stappers, 2008), demanding the application of many 21st-century skills. The purpose of this preliminary research project is to investigate how 21st-century skills are developed when Key Stage 3 students (age 11-14 years) work as designers engaging in a participatory design process, as part of the design and technology curriculum.

'21st-century skills' include creativity, critical thinking, collaboration, communication, and digital literacy and are widely considered as necessary for individuals to adapt to new challenges and opportunities, and to solve complex problems (OECD, 2019a). Creativity, critical thinking, and collaboration form the focus of this project, with empathy being essential in all three. D&T is a subject in the National Curriculum for schools in England (DfE, 2013) which is uniquely placed to develop these skills; it requires students to engage in a range of designing, making, and critiquing activities (McLain, 2023), contributing towards an overarching knowledge of 'design and technology'. It also requires students to utilise skills such as critical thinking, creativity, and communication to solve problems in different contexts, as well as applying technical skills such as manipulating materials and components using tools and equipment.

Participatory design is pertinent to the development of 21st-century skills, as it requires collaboration and communication with peers and users, the development of empathy, and the ability to think creatively in relation to problems and solutions. [cite] Evidence of studies focusing on human-centred or empathic design at primary and secondary school level is scarce (Bosch et al., 2022; Dindler et al., 2020), therefore, this study aims to contribute to and expand upon this emergent body of knowledge by exploring a case study of a preliminary project aimed at facilitating sustained face-to-face interactions between end-users and lower-secondary aged students, towards collaboratively solving an identified problem through designing and making.

30 LITERATURE REVIEW

30.1 21st Century Skills and Interaction with End-Users

The literature highlights that design education is going through a period of transition (Bakirlioğlu et al., 2016), blurring the lines between design and design research (Shore et al., 2018), revealing the potential of considering user knowledge, human factors, experiences, and interactions in the engagement of participatory practices with end-users and stakeholders. Human-centred design is emerging as a dominant trend (Chmela-Jones, 2017), contributing towards the shift in design education towards a more participatory form of practice (Bakirlioğlu et al., 2016; Shore et al., 2018). The value of involving end users in a participatory design process lies in learning different 21st-century attributes and in producing design outcomes (Bosch et al., 2022).

21st-century skills are featured widely in design education literature, noting social and emotional skills as being particularly relevant in preparing students for navigating working life (Demetriou & Nicholl, 2022; Mitchell & Light, 2018). There is much discourse on the skills of problem-solving, creativity, and empathy within design education, however this tends to lie within the higher education space. In pertinent studies to the focus of this topic and its relation to schools, Bosch et al. (2022) and Klapwijk and Van Doorn (2015) note that the value of involving end-users in the participatory design process is in the students' development of 21st-century skills, especially empathy.

30.2 Empathy and its Relevance in a D&T Curriculum

When empathic design first appeared in business literature in the late 1990s, it was described as a cultural shift (IDEO, 2014). It was then that companies started to realise that only noting customers' responses through questionnaires was not enough to develop successful products (Koskinen and Battarbee, 2009). Whilst this phenomenon was gaining traction in the business world, it too was a key feature of the National Curriculum for D&T in England, beginning in the 1993 National Curriculum "…including some contexts with which they are initially unfamiliar." (DES/WO, 1992, p.24) Although the term 'empathic design' is not explicitly included, the concept itself plays a significant part in D&T Programmes of Study from this point, including in its present iteration. Focusing on the user as a vehicle for the development of other skills and knowledge within D&T has the potential to contribute to the subjects' uniqueness and perceived value.

30.3 Opportunity

To understand a problem fully, students are encouraged to conduct a significant amount of research (Hill, 1998); whilst there are many ways of researching user needs in order to develop an understanding, literature advocates the development of a relationship between students and end-users within problem-based contexts (Jones, 2023). A lack of designer/user contact is a serious limitation to good design because ongoing contact between designers and users allows designers to gain first-hand knowledge from their intended audience (Denton and McDonagh, 2003), however school structures often reduce the likelihood of regular designer/user contact, where the students take on the role of designer within their D&T studies. As a result of a lack of time and students' understanding of contexts, the design process can be described as being stunted, leading to poorer outcomes (Demetriou & Nicholl, 2022); this is also often the case in the professional design world where designers do not spend enough time experiencing the user's 'world', therefore they may be reluctant to immerse themselves in it, as the activity is not necessarily solution focused (Kouprie and Visser, 2009). This study attempts to address the constraint of time within a school curriculum, providing an opportunity to study the effects of facilitated sustained interaction between students and end-users within D&T lessons.

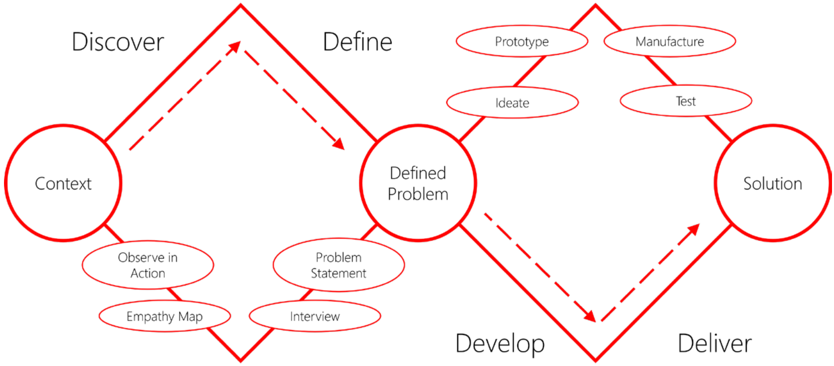
31 METHODOLOGY

This case study was conducted in a secondary school in North-West England as part of students' Year 8 (age 12-13) D&T curriculum. Sixteen students working in teams of four, one teacher-researcher and four members of the school catering staff (end-users) participated in the project. In order to maximise the development of empathy, it was important that the end-users were different to the students themselves. The catering staff were selected for this preliminary study because there are clear differences in age and experience to the students and face-to-face interaction was relatively easy to arrange at regular intervals. I, as the teacher-researcher, present an ethical dilemma in that there is a clear power dynamic between the students and I, therefore the way in which the study was presented to the students in the first session was designed so that it was very clear that the outcomes of the project were the focus of the study, rather than in teaching, learning and assessment, and that the questionnaire was anonymised. For the purposes of school assessment, it was solely the way in which students worked collaboratively that was reported on.

The study began with a self-reporting questionnaire 'The Creative Personality-Potential Composite' developed by Shepard (2019), containing questions relating to problem-awareness, novelty, complexity, sensitivity, non-conformity, independence, flexibility, and fluency. This questionnaire was selected due its validation in a sample of 1076 respondents and its questioning style being suitable for use by children. The above categories based can be attributed to different 21st-century skills; however, its main aim is to measure creative potential, a valid instrument for the purpose of this study. This questionnaire was completed again at the end of the intervention in order to analyse any changes.

The Double Diamond Model (Design Council, 2005) was used as a basis for the intervention design, utilising a range of activities inspired by aspects of the Delft Design Guide (van Boeijen et al, 2020) and The Design Thinking Toolbox (Lewrick et al., 2020), as shown in Figure 1. Participants met on four occasions during the project, first for the students to observe the user in action, second to interview the users, third to present and refine ideas, and finally to test out their prototypes.

Figure 1. Intervention Design



32 4. DATA COLLECTION AND ANALYSIS

The project was designed to be delivered over twelve 55-minute sessions, however due to teacher strikes, extra-curricular events, teacher training days and bank holidays, this was reduced to a total of eight sessions, thus requiring the students to periodically complete activities at lunchtime. Two of the student participants developed long-term illnesses during the project and were therefore absent and unable to complete it; this also meant that two of the teams of students were reduced to three members for much of the project. Several students were absent in the final lesson, which meant that post-data was not available for all participants.

The design work and practical outcomes were thematically analysed based on developing themes, in addition to an analysis of themes emerging from changes in the pre and post questionnaire.

33 RESULTS

The problems identified by each participant team were varied and well-defined. The solutions they aimed to develop were:

- *Group 1* A way to safely transport cooked pasta from the kitchen to a servery.
- *Group 2* A way to prevent students from throwing metal cutlery in the bin when removing food waste from their plate.
- *Group 3* A way to organise consumables in a café to improve efficiency.
- *Group 4* A way to reduce queues by developing an interactive ordering and collection system.

The pre and post questionnaire highlighted a slight improvement in 'creative potential' overall. Interestingly, it was the teams of participants that completed a more prolonged iterative process (Group 1 and 2) that reported more improvement to skills, especially empathy, highlighting the importance of a prolonged interaction with the end-users. The design work completed by students gave a much more detailed picture of how skills were developed during the process. The outcomes of the four teams are shown in Figure 2-5.

Figure 2: Group 1 Outcome

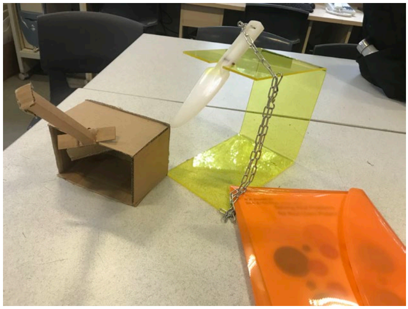


Figure 3: Group 2 Outcome

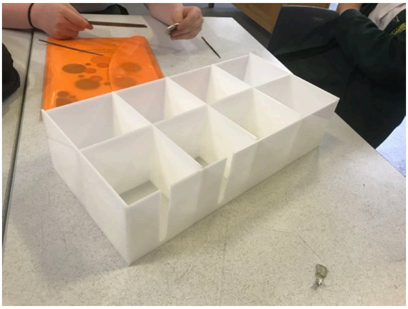


Figure 4: Group 3 Outcome

Figure 5: Group 4 Outcome

34 DISCUSSION

Whilst the questionnaire led to some interesting results, its suitability for measuring 21st-century skills more generally is limited, therefore a questionnaire designed specifically for measuring these skills would be sought or developed to better understand how these skills are understood and developed by students. In the post-questionnaire, it would have been useful to have some open-ended questions to elicit more detailed responses about students' perceptions of different skills and their experiences of the intervention.

As the teacher-researcher, I was able to reflect on all aspects of the intervention. I was surprised by the confidence of students when interacting with adults they are fairly unfamiliar with; they were able to develop relationships very quickly and their empathy was evident when discussing their interactions and in their design work. As an open-ended project, the participants were able to define their own problems, however this did prove difficult for some who required prompting. The aim of the project was to develop a functional prototype using materials, components, tools, and equipment, however the versatility of the problems that were defined meant that there was opportunity for participants to pursue more conceptual products. There was a tendency to design solutions that were incredibly ambitious, containing complex electronic and mechanical systems, which led to the need to advise participants on more appropriate ways of tackling the problem, in line with the intentions of the project, which felt limiting and contrived at times. The project lends itself well to designing creative, complex solutions to problems and has the potential to cover many aspects of the National Curriculum, however the intention was also to include the 'make' aspects of the curriculum. There was an ongoing need to intervene and prompt participants, arguably the modus operandi of a D&T teacher, requiring the need to regularly step in and out of researcher and teacher roles.

Students were not confident when generating ideas and tended to become fixated, this phase would need to be developed to support students in generating more varied ideas.

The data collection methods were limiting. There were many interactions, statements and actions that remained uncaptured during the project, therefore in future investigations, teachers would be encouraged to keep field notes to support analysis. Whilst students were encouraged to photograph their journey, many neglected this and then found it difficult to reflect on the development of their prototype later. As the teacher, I was able to witness the considerably increased level of motivation and commitment to their individual projects compared to my ten years' experience of other units of work at Key Stage 3; this is an area that could be explored further.

One of the teams produced a rough prototype for an ordering and collection system (Figure 5) that they would have been unable to make functional, therefore they were tasked with pitching their idea to the school's Business Manager in order to improve the rigour of their experience. On reflection, this should have been a key part of the project for all participants, enabling the development of more skills and providing further opportunities for analysis. In subsequent investigations, students will be required to present their entire design process, narrating the decisions made and obstacles they overcame. The use of video for this phase would be useful to capture as much data as possible.

34.1 Limitations

This study involved a very small sample of participants. Whilst the intention was never to generate generalisable findings, it would be beneficial to expand the study to include more groups of students in the future to increase the rigour and reliability of the study. A lack of field notes from the researcher, as well as a lack of recorded key moments from participants reduced the scope of data considerably, therefore careful planning and consideration to recording ideas would need to be taken. A reflective journal, culminating in a presentation of participants' journeys would mitigate this loss of data and provide further opportunities for analysis later.

35 CONCLUSION

This preliminary research project has demonstrated that there is potential for 21st-century skill development by engaging with authentic end-users. Whilst common at Key Stage 4 and 5, the design of a 'real-world' project such as this is a departure from typical practices at Key Stage 3 D&T and requires further exploration. The project aligns with the ambitions of the Design and Technology Association, whose paper entitled 'Reimagining D&T' (2023) highlights the potential for the subject to be a key aspect of the curriculum to develop human skills, alongside technical expertise. It also emphasises that change is required at Key Stage 3 in England, focusing more on succession from a now-rigorous Key Stage 2 experience and moving away from routine making activities that often culminate in identical 'end-products'.

The contexts provided to students in this preliminary project ensured that there was some familiarity to students, however it would be interesting to investigate whether more open or obscure contexts has an impact on skill development. The *'Solving Genuine Problems for Authentic Users Project'* will be conducted from October 2023 involving 160 students and 40 end-users from within and outside of the school, focusing on solving genuine problems identified collaboratively between students and the end-users.

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Artificers, Satisficers and Optimisers: Echoes of Simon and 'Ways of Being' in Design and Technology Education

Steve Keirl, Goldsmiths, University of London, s.keirl@gold.ac.uk

ABSTRACT

Herbert Simon created the neologism 'satisficing' in order to address a particular issue he found regarding problem solving in organisations. His work also included such concepts as 'bounded rationality' and has influenced many areas of human endeavour including, at times, the theorising of problem-solving in Design and Technology (D&T) education.

The paper gives an overview of Herbert Simon's work and neologism, drawing on his landmark text *The Sciences of the Artificial* (Simon, 1969/1996). Context is offered with comparisons between the (positivistic) problem-solving of the technical-rational 1960s zeitgeist and subsequent human-centred design practices and genres.

Imagining three 'ways of being' in the field of D&T, the paper explores how the roles of *artificer*, *satisficer* and *optimiser* can play out for pupils, teachers and D&T's problematic (sic) curriculum. Whilst echoes of Simon's work can still be found in D&T education, and the three roles can contribute to the design repertoire of pupils and teachers alike, it is argued that any application of them should be understood for their limitations as 'problem-solving' cannot equate designing – in theory or in practice.

Keywords Satisficing, Design history, D&T curriculum, The artificial, Climate emergency.

1. INTRODUCTION

The great materialist expansion of the post-World War Two years warrants reflection in the context of today's climate emergency; not least because the *practice of design* was/is central to all technological and material development, that is, the development of *the artificial.* (This includes the associated political decision-making and policy formulation which are also 'artificial').

The post-war period was one of dominant technical rationality with burgeoning developments in social and natural sciences, technological creativity, capitalist growth and consumerism, alongside great optimism about what could be achieved globally. Despite all the creativity, optimism and growth, the period was not without its siren critics. Papanek opened his 1972 text with these words:

> There are professions more harmful than industrial design, but only a very few of them. And possibly only one profession is phonier. Advertising design, in persuading people to buy things they don't need, with money they don't have, in order to impress others who don't care, is probably the phoniest field in existence today. (Papanek, 1972:9).

(For more on post-war mass consumerism and waste see Packard, 1962 & 1963).

In 2005, Thakara reflected on matters thus:

> Many of the troubling situations in our world are the result of design decisions. Too many of them were bad decisions…The parlous condition of the planet, our only home, is a good example. Eighty percent of the environmental impact of the products, services, and infrastructures around us are determined at the design stage…we designed our way into the situations that face us today. (Thakara, 2005:1)

In the 1960s design itself had been undergoing re-design. Cross (2007) reports that these were the years when there were aspirations to 'scientise design'. Polymath Buckminster Fuller had called for a 'design science revolution' naming the 1960s as the 'design science decade.' (Cross, 2007:119). Dorst & Dijkhuis (1996), report the emergence of 'first generation' design methodology in the early 1960s and the rationalising nature of its positivist background. 'Criticism of these models raised interest in the fundamentals of design theory, the logical form and status of design. It also fostered a need for more detailed descriptions of the design activity…' (Dorst & Dijkhuis, 1996:253). A key protagonist of an analytic approach to design was Herbert Simon.

37 OVERVIEW OF SIMON'S NEOLOGISM AND RELATED WORK

Herbert Simon (1916-2001) held a PhD in political science and his extensive research addressed (amongst others) artificial intelligence, organisation theory, decision-making, cognitive science, information processing and complex systems. His influential text *The Sciences of the Artificial*, appeared in 1969 and ran to three editions (1969, 1981 and 1996), each being revised and updated to incorporate contemporary developments or to revise Simon's theoretical position. This paper references the third edition (Simon, 1996) although the concepts addressed are from the original.

Simon's significant contribution towards the culture of the times (and subsequently) included the theorising of problem solving and decision-making across organisations, engineering and emergent computer science; and design is at the core of this work. His problem-solving theories; '…provided a framework for (an) extension in the scope of design studies…within the paradigm of technical rationality…(as well as providing)…a sound, rigorous basis for much of the existing knowledge in design methodology.' (Dorst & Dijkhuis, 1996:253). This paradigm remained dominant for many years and traces of its influence remain today.

It should be noted that Simon eschews the colloquial negativity often associated with talking of something being 'artificial'. He wrote of using '…"artificial" in as neutral a sense as possible, as meaning man-made (sic) as opposed to natural.' (Simon, 1996:4). (This simple dualism is not, of course, unproblematic.). Also, in line with others, Simon observed that the natural sciences are concerned with how things *are* and with *analysis;* whereas, engineering is about *synthesis* and that:

> Synthetic or artificial objects, and more specifically prospective artificial objects having desired properties – are the central objective of engineering activity and skill. The engineer, and more generally the designer, is concerned with how things *ought* to be - how they ought to be in order to *attain goals,* and to *function*. (Simon, 1996:4-5. Original italics)

He also considers that: ‘Everyone designs who devises courses of action aimed at changing existing situations into preferred ones’ (Simon, 1996:111); a definition Margolin describes as ‘deceptively catholic’ (Margolin, 2002:236). However, such statements do contribute to the defensible case for design education as a component of general education (for all students).

37.1 Simon’s neologism

Key to designerly practice is the weighing up of competing variables, a form of decision-making well engaged by Simon. This paper cannot address the detail that Simon applies to the decision-making involved in bringing anything artificial into being. However, it does take a focal interest in a neologism that Simon coined; that of *satisficing*.

According to Simon, try as we might to get the best possible result when designing the ‘artificial’ we can rarely achieve this. We seek the optimal (he calls it optimisation) but we can only compare ‘better’ or ‘worse’ or ‘…(we accept) ”good enough” alternatives, not because less is preferred to more but because there is no choice.’ (Simon, 1996:29). He says: ‘Since there did not seem to be any word in the English language for decision methods that look for good or satisfactory solutions instead of optimal ones, …I introduced the term “satisficing” to refer to such procedures’ (Simon, 1996:119). His term combines two words, *satisfy* and *suffice*, to create the verb *to satisfice*. Vincenti (1990) describes how one group of aeronautical engineers, using their judgemental skills to address the complexities and uncertainties in a problem, ‘…probably saw themselves as optimising…’ whilst actually only achieving satisficing solutions. (Vincenti, 1990:220).

Simon shows that one of the reasons that satisficing occurs is that, no matter how rational our decision-making may be, when applied to multiple variables (in what he calls the *problem space*), our rational options are necessarily limited if success is to be achieved; thus, we satisfice rather than optimise. He describes this as *bounded rationality*. He offers two examples of ‘triumphs of bounded rationality’: the writing of the American constitution; and, the landing of humans on the moon (Simon, 1996:140), suggesting elsewhere that ‘…bounded rationality…is most comfortable with clear-cut and limited goals.’ (Simon, 1996:150).

Satisficing, then, comes into play when all design variables in a given design situation have been *satisfactorily* met. If all variables can be optimally satisficed, then optimisation would be reached. This, says Simon, can rarely happen. Equally, should some variables not be satisfactorily addressed, then satisficing itself cannot occur.

37.2 Further context to Simon's work – alternative paradigms and perspectives

Simon's approach can be further contextualised by considering other theorisations of designerly practice over subsequent years. This is useful for framing our questions regarding education. For example, Dorst & Dijkhuis (1996) draw on the work of Simon and of Donald Schön to compare two paradigms: respectively, the 'rational problem-solving paradigm' and the 'reflection-in-action paradigm'. (Dorst & Dijkhuis, 1996:255)

Schön (1983) resisted the prevalent positivist-analytic framing of 'problems' and 'solutions' and took a human-centred approach, seeing design as a reflective conversation with the situation. He suggests that:

> If the model of Technical Rationality is incomplete, in that it fails to account for practical competence in "divergent" situations, so much the worse for the model. Let us search, instead, for an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict. (Schön, 1983:49)

In line with positivist tendencies, design practice had been heavily influenced by the 'form follows function' dictum from the outset of the 1900s. Archer (2006) describes how that dictum, along with other significant 'advances in design thinking' across the Century, all failed to compare with the 'paradigm shift' (after Kuhn, 1962) he saw taking place in the late 1990s.

The paradigm Archer refers to is that of the *semantic turn*, attributing its roots to Krippendorff & Butter (1984) and foregrounding the individual and cultural meanings of things rather than their form, structure and function. Krippendorff (2006) puts it this way:

> The semantic turn challenges designers' blind submission to a stable functionalist social order, which is anachronistic to the kind of society experienced today…(and, citing Simon, he argues that)…(The) producer-product-profit logic dominated decision-making during the industrial era…an era of scarce material resources and hierarchical social structures, coupled with an unwavering belief in technological progress... (Krippendorff, 2006:6-7)

Krippendorff, like Schön, advances a human-centred design culture as a response to the functionalist society and offers a basic proposition that: 'Design constitutes being human' (Krippendorff, 2006:74). Indeed, he proposes design as: '…a fundamental human right, the right to construct one's own world, interact with fellow human beings in theirs and make contributions to the ecology of humanly accessible artifacts.' (Krippendorff, 2006:322). He advocates *participatory design* where all stakeholders are co-designers sharing and advancing a common design culture.

For further critique and context of Simon's approach to design see Margolin (2002), in particular, two of his essays. First, *The Two Herberts* in which he sees Herbert Simon's scientised definitions of design theory and practice exemplifying Herbert Marcuse's (1968) 'technological rationality'. The essay alerts us to the dangers of conceiving of a design 'discipline' based on such a framework; '…an unwelcome reference point for the legitimation of design as an academic subject' (Margolin 2002:234-243). Margolin's preference is for '…a much more open conception of design activity that is not preoccupied with justifying a separate sphere of domain knowledge, as the primary purpose of (design) research'. (Margolin 2002:237). Second, is Margolin's titular essay The Politics of the Artificial which he himself describes as a polemical play on Simon's original. (Margolin 2002:5 and 106-123).

Notwithstanding the critiques and perspectives on Simon, we can summarise by saying that: a) his work was very much 'of its time'; b) his work was hugely influential across many fields, of which, design was one; and, c) his attempts at establishing a *science of design* have not stood up to universal acceptance; particularly by designers themselves.

(For more on the *relationship* between design methodology and science, see de Vries et al., 2003).

38 SIMONIAN 'WAYS OF BEING' IN D&T EDUCATION

Drawing on Simon's neologism, three roles as 'ways-of-being' suggest themselves. The first is that of *satisficer*, that is, those who work to *satisfice* in any given situation of learning or change. They strive to address to a satisfactory level all variables in a situation whilst possibly optimising some variables. Satisficers recognise that totally optimal outcomes are rare. Thus, satisficers could operate on a 'that'll do' (minimalist approach) or a 'that is the best that can be done' (maximalist approach). In the game of 'design as the weighing-up of competing variables' the satisficer is ever-challenged to treat all variables symmetrically, that is, with equal consideration.

Thus, second, it remains possible to conceive of players as *optimisers* – those who strive for the optimum for all criteria. However, while an optimiser might be judged naïve in trying to optimise all variables, there is another potential dimension to their approach. Drawing on the related sense of *optimism* – a positivity that enables a vision or a goal – the optimiser brings something that the utilitarian satisficer need not entertain. It may be that the optimiser envisages criteria that are beyond those of a situation's requirements at the utilitarian level. An optimiser may arrive at a *possibility* that reaches beyond satisficing because they are reaching beyond a 'that'll do' level into an area of risk-taking.

'As soon as we introduce "synthesis" as well as "artifice" we enter the realm of engineering".' (Simon, 1996:4). It would seem reasonable to consider a third group who have over millennia contributed to technological development and its (positive and negative) outcomes – the *artificers*. The term is less-used now but an artificer was a skilled craftsperson, someone clever at devising things, possibly an inventor. The artificer is the doer, a producer, a person who delivers. An artificer may simply 'make to order' – creating, to a high degree of quality, that which has been specified by others. Or, they may be an independently inventive creator or problem-solver who delivers what is required, but has perhaps not been fully specified, by others. Artificers may simply follow/fulfil orders or they may embrace a critical ethic, weighing-up the consequences of their works in the world-at-large.

38.1 Pupils and teachers as satisficer, artificer, optimiser

A pupil or student can, through their design education, learn the differences amongst the *acts* of satisficing, artificing and optimising; as well as their limitations. When weighing-up a design situation or considering pathways to pursue in a particular project they can act strategically in how they move amongst the roles. By learning of the potentials and pitfalls that each role offers, they gain design experience. To apply Schön (1983), by reflecting-in-action they can understand that these are more than just strategic roles but are potentially ways of being in the world. Further, they may learn about differences between positivist problem-solving and designerly choice-making (see, e.g. Keirl & McLaren, 2013). They may identify with a particular role or they may understand how others play such roles in life. Further, understandings about how designs and technologies come into being as a result of human agency can develop alongside a knowledge of the differing impacts players can have on technological developments.

Central to all activity in the classroom is the teacher who is, de facto, the arbiter of curriculum, school policy and students' learning. Teachers can readily be seen or positioned in any of the three roles. It may be a matter of personal professional philosophy to choose to work in a particular way or it may be that the individual merely does what is expected of them at a basic level. Compare, for example, the teacher who sees themselves as deliverer (to the best of their ability) of a syllabus to get their students through an exam, with the teacher who works to educate students about the three roles and their significance to D&T projects as well as to the wider world. The former sees teaching as the efficient delivery of content, a teacher-centred approach, while the latter uses D&T projects to enhance understandings of these ways of being in the world using student-centred pedagogies. In the classrooms of the latter, students and teachers alike may be any or all of satisficers, optimisers and artificers.

39 ECHOES OF SIMON IN DESIGN AND TECHNOLOGY (D&T) CURRICULUM DESIGN

While we can see pupils and teachers playing out their Simonian ways of being, we cannot ignore the bigger curriculum context which shapes just how, and how far, the roles may be enacted. Reviewing Simon's considerations of *the creation of the artificial* and recognising that curriculum itself is a designed artifact, the following topics resonate as familiar issues, that is, locators for curriculum contestation, design or re-design. Each *could* be thought of as a 'problem' seeking a satisficing solution. The list is neither comprehensive nor prescriptive.

Design and Technology education's role in:

- improving the damaged world that our children are inheriting - and for which they will be responsible;
- general education and in supporting designing as a way of *being human*;
- raising public awareness of the centrality of design to any technological development;
- deepening public participation in design decision-making;

D&T's marginalisation by:

- instrumental-functional economic and educational policies;
- OECD/PISA-driven testing regimes (Organisation for Economic Cooperation and Development/Programme for International Student Assessment);
- STEM agendas;

D&T's identity issues:

- the case for dropping/maintaining the 'D&' in D&TE;
- the value, or otherwise, of trying to locate D&T around a defined body of knowledge;
- 'subject'; 'discipline'; 'field of education'; 'learning area'; or, 'a literacy';

D&T's pedagogical challenges:

- holistic rather than reductionist approaches to learning;
- positivist valorising of technological 'problems' to be 'solved';
- the problem of teaching singular design 'processes' that do not mirror the realities of designing – epistemologically or praxically.

Such a list invites the question: "So can satisficing work here?" We might say these are problems that cannot be satisficed because, to adapt Simon's term, any associated rationality is un-bounded. Whilst all such curriculum issues interrelate, to re-design any one is to influence others. After all, curriculum is, as Pinar (2004:188) says, a 'complicated conversation'.

When the issues listed are unlikely to be resolved by even the most enlightened of satisficers we might say that their resolution is impossible. However, the teacher-as-satisficer who is allowed the professional freedom and judgment to more truly be the arbiter of curriculum and learning has a better chance than the teacher with dictated curriculum constraints. Alternatively, the issues might be reframed by the adoption, at macro and micro levels, of design genres more appropriate to the task than 'problem solving' (whose 'solutions' often beget yet more 'problems'). Some candidate methodologies here would include ecological design, speculative design, participatory design, and critical design – all human-centred approaches.

40 SUMMARY

It would be unreasonable to dismiss the educational potential of Simon's approach and neologism. It clearly has a role in *some* design education situations. However, its limitations lie in its technical-rational context which cannot entertain design strategies that are necessarily open and messy. What interweaves the challenges on the list are matters of philosophy and politics for curriculum designers and teachers alike. This calls for an enlightened and critical D&T profession and a curriculum liberated from many of the current instrumental constraints (see, for example, Pitt & Webster, 2021 on hope, democracy, experience and reflection).

There are many ways that designerly pupils and teachers can 'be' in this world and Simon's work has pointed to just three. Design and Technology Education has an undoubted role to play in helping educate a populace of citizen-designers (Resnick, 2016) who understand both the centrality of design to all technological developments and the non-neutrality of technologies (including its problem-solving strategies!). While echoes of Simon's work in some ways fade, they can still resonate in some of D&T's own complicated curriculum conversations.

41 CODA

The motivation for this paper arose from seeds sown by Howard Middleton (1998) and colleagues (e.g. Stevenson, 2003) in the Australian Technology Education Research conferences of the early 2000s. An itch has been scratched!

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Secondary Students Intrinsic Motivation during Multidisciplinary STEAM projects

Remke M. Klapwijk, Delft University of Technology, r.m.klapwijk@tudelft.nl

ABSTRACT

Education is usually organized along the line of mono-disciplines. It is however argued that a focus on solving problems, designing and advising for clients will be more meaningful for students and will enhance their motivation for Science, Technology, Engineering and Mathematics subjects and careers. Therefore, the Dutch network of Technasia schools have positioned Integrative STEAM projects for clients central in their curriculum.

Usually these projects are related to one discipline and conducted by students with a science-oriented profile. In a pilot, 8 schools developed and conducted Multidisciplinary STEAM Projects for pupils in grade 9 to 11 using social cooperative approaches such Jigsaw and perspective-based question prompts that scaffold multi-disciplinary ways of thinking.

The self-determination theory links intrinsic motivation with the presence of autonomy, relatedness, perceived competences. The theory also links the way students perceive the relevance of their learning activities to motivation. Therefore the Intrinsic Motivation Inventory (IMI) questionnaire was used to determine half-way and after the project of 182 students their interest and enjoyment as well perceived competence, effort, pressure, perceived choice, value/usefulness and relatedness. For relatedness to peers and to the client the original statements from IMI were adapted. The results show that intrinsic motivation was slightly positive on average, while relatedness between teammates was positive and pressure low. Students experienced working from different disciplines as valuable. It is suggested to develop new items to measure relatedness to the client as those based on the original IMI where not able to measure this construct well.

Keywords: Self-determination theory, Motivation, Multidisciplinary Projects, Secondary Design and Technology Education, Integrative STEAM, Jigsaw

1. INTRODUCTION

Motivation for Science, Technology, Engineering and Mathematics (STEM) is crucial for the development of perseverance and to perform well. However, many studies show that motivation for STEM subjects tends to decline during secondary education (Crawford 2014: Potvin & Hasni 2014, Barmby et al. 2008; Teppo, Soobard, & Rannikmäe, 2021). Among the reasons given, it is thought that many students are not particularly interested in STEM when subjects are given in a rather abstract, mono-disciplinary way (Teppo et al., 2021). This approach would work well with personalities that John Holland defines as having realistic or abstract preferences, but does not seem well suited for those who are driven by social or artistic preferences (Klapwijk & Rommes, 2009).

Integrated STEAM (science, technology, engineering, arts and mathematics) programs may provide a richer image, enable students to develop a great many skills like entrepreneurship and creativity that are not present in the traditional, mono-disciplinary subjects and this may increase student's motivation for learning. Based on this idea, the Dutch Curriculum has undergone a reform and two integrated STEAM subjects have been introduced: Nature, Life and Technology and Research & Design. Both subjects emphasize the value of learning and applying knowledge of science and technology for social, entrepreneurial and creative questions, therefore the term STEAM is more appropriate than STEM.

The subject Research & Design is especially unique as all learning is based on projects developed by teachers in conjunction with local organizations and in the later grades by students themselves. The client will present the problem at the start of the project and secondary students will use their expertise to propose solutions. Usually, the projects are developed around one specific profession or discipline, e.g. an architect. Currently more than 100 Dutch secondary schools that are part of the Technasium network offer the subject for pupils aged 12 to 18.

In a pilot, Technasium teachers developed projects that take more than one profession or discipline into account. In these projects, students were asked to combine insights from different disciplines to shed light on the question from the client.

Although it is often conjectured that Integrated STEAM leads to an enhanced motivation, systematic research is needed. Vossen and colleagues studied motivation of Dutch Research & Design students, but their study was not related to specific Integrated STEAM projects (Vossen, Henze, Rippe, Van Driel, & De Vries, 2018). The aim of our study is to measure the intrinsic motivation of Dutch pupils for Integrated STEAM projects using a multidisciplinary approach. Specifically, the researchers answered the question what is the level of motivation of the students during and after doing an integrated multidisciplinary STEAM project in terms of a) interest and enjoyment, b) perceived competence, c) effort, d) pressure, e) perceived choice, d) value/usefulness, and relatedness (Centre for Self-Determination Theory, 2023). Also, the aim was to make an existing questionnaire on motivation suitable for use in the context of multidisciplinary STEAM projects for clients.

43 LITERATURE REVIEW

Previous research on academic motivation has produced a number of theoretical frameworks. All of these theories state that motivation involves internal processes that initiate and maintain goal-directed behaviours (Pintrich & Zusho, 2002). According to the Expectancy-Value theory

(Wigfield & Eccles, 2000) motivation is related to students' beliefs about themselves (expectations) and to the value students assign to certain tasks. Wigfield and Eccles state that the motivation to perform tasks increases when the expectation of success increases, students expect that they will succeed in performing the task well, and the task is perceived as valuable.

Most theories of motivation distinguish between different types of motivation. The self-determination theory (Ryan & Deci, 2017) distinguishes intrinsic from extrinsic motivation. Intrinsic motivation is about the interest and pleasure in the learning activity itself ("I enjoy doing the task), extrinsic motivation is about what doing the task will yield, you can think of a reward, but also the value for someone's personal goals, now and in the future or the value for a client, users or society. Integrated STEAM projects are expected to lead to both types of motivation. Students may enjoy the activities as such and experience the relevance of STEAM as they solve issues for local clients and society.

Self-determination theory links intrinsic motivation with the presence of autonomy, relatedness and perceived competences. These are considered basic needs that need to be met in order to be motivated to learn. A series of qualitative case studies into design education in primary schools (Roël-Looijenga, 2021) and a quantitative study in grade nine (Chiu, Chai, Williams, & Lin, 2021) confirm that these needs are relevant for integrated STEAM projects. However, autonomy is not always beneficial, namely when students are given too much freedom of choice and are unable to work purposefully in a design project (Roël-Looijenga, 2021). From social innovation theory, it is also known that to achieve social innovations these basic needs need to be met. Avelino, Dumitru, Cipolla, Kunze, & Wittmayer (2020) demonstrate this for sustainable innovations and describe that innovations were kept going – even going against the grain – when basic needs where met.

Feelings of fear and stress that students may have also play a role. Fear can hinder learning, lower performance and reduce the enjoyment of learning. Feelings of anxiety are a problem for STEM, but maybe less so for STEAM. Anxiety is more common among girls although differences seem to be small, e.g. in the context of math (Dowker, Sarkar, & Looi, 2016) or during integrated STEAM activities (Vossen, Henze, Rippe, Van Driel, & De Vries, 2018).

44 METHODOLOGY

44.1 Participants

The participants were ten teachers and their secondary school students (grade 9 to 11) of eight Technasium schools across the Netherlands. Data were collected from September 2022 to June 2023. Most students followed the Research & Design track and had prior experience in STEAM project work. In total, 182 unique students filled in a complete or almost complete questionnaire and 92 of these filled in both the mid- and post-questionnaire. Two teachers conducted the multidisciplinary STEAM projects with non-Research & Design students, 49 unique respondents had no prior experience with STEAM projects. Students from grade 9 to 11 with different study profiles and education levels were involved. In the Dutch system, students select a profile at the start of grade 11. Nature and Technology and Nature and Health profiles focus on science, the

Economy and Society profile on gamma studies and the Culture and Society profile on Humanities. The aim was to involve students with different profiles in the multidisciplinary projects. However, most schools did not achieve a balanced mix of profiles. Participants came from the VWO level (prepares for universities) as well as the HAVO level (prepares for universities of applied sciences).

Table 15.
Participants.

Category		**Mid-questionnaire**	**Post-questionnaire**
Gender	Boys	105	96
	Girls	45	35
	Other, Don't want to tell	6	5
Track	Research & Design	130	101
	Non Research & Design	26	35
Profile	Nature & Technology	67	53
	Nature & Health	39	33
	Economy & Society	39	45
	Culture & Society	11	5
Grade	9	91	60
	10 &11	57	69
	Unknown (9-11)	8	7
Total		156	136

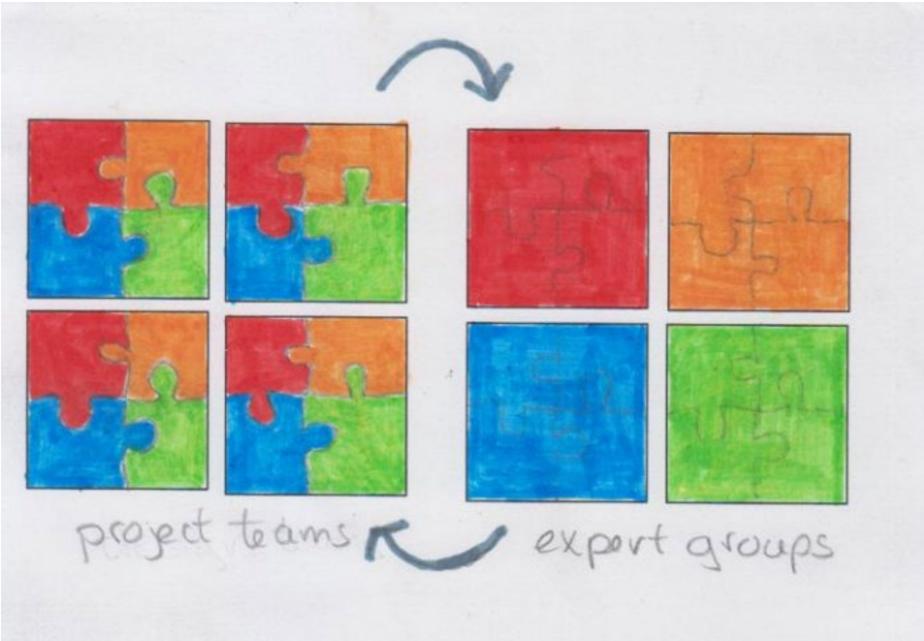
44.2 Multidisciplinary STEAM projects

In the educational philosophy of Technasium, teachers develop R&D projects with local clients and experts. To obtain ecological validity, this procedure was also followed in this research and each school conducted a unique STEM project, including a project on local hydrogen use, meat substitutes, repurposing old school buildings and local recycling of waste in a care institute.

Normally a Technasium project is only related to one profession, in the pilot with eight schools, a new kind of project was developed. Common was the multidisciplinary project approach. This approach was new for all teachers and students. All teachers provided their students with a multidisciplinary challenge related to four to six disciplines, During the pilot, teachers discussed how to support multidisciplinary team work and a number of tools were presented by the researcher. The social cooperative Jigsaw method (Aronson, 2023; Slavin, 2015) and a Perspective-based Generic Questions Tool were applied in many projects.

In Jigsaw, illustrated in Figure 1, students combine working in project teams groups with working in expert groups. Students were initially placed in a project team to solve the problem or challenge posed by the client. The students then left the project teams to work in expert groups After they had become experts in the different disciplines related to the project, they returned to their project teams to exchange information and use all the disciplinary perspectives to solve the problem or question at stake. This process requires students to explain their perspectives and integrate perspectives to create solutions. For example, in the project on meat substitutes students were divided into four expert groups, namely sociologists, food technologists, nutritionists and marketing experts. Each expert group had a meeting with an expert in "their " field, studied the problem together and then returned to their design team for joint problem solving and designing alternatives for meat. In traditional Jigsaw, students only explain the subject matter to each other, in our approach – which we could label Jigsaw 3 – they integrate knowledge into a design or advice for the client.

Fig 1.
Jigsaw 3 Approach in D&T projects based on Aronson, 2023.



The Perspective-based Generic Questions Tool is meant to scaffold teachers as well as students' questioning (De Boer, Janssen, van Driel, & Dam, 2021). The tool consists of cards for various disciplines each containing a series of general, domain-specific questions to inspire and support novices who have not yet highly detailed knowledge to come up with questions themselves. Many teachers in our study used the tool to develop their project and select questions, while other teachers gave the cards to their students to select relevant disciplines and questions for their project, providing the students more autonomy. See appendix A for an overview of the projects and conditions.

44.3 Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) (Center for Self-Determination Theory, 2023) was used to design a questionnaire. The IMI is a multidimensional instrument with 45 items on interest/enjoyment, perceived competence, effort, pressure, perceived choice, value/usefulness and relatedness that was adopted from earlier studies (McAuley, Duncan, & Tammen, 1987; Center for Self-Determination Theory, 2023). It specifically allows to assess intrinsic motivation during and after activities have been done.

IMI has been implemented in different contexts, including science education (Teppo et al., 2021), and Integrative STEAM programmes (Chiu, 2022; Jones, McDermott, Tyrer, & Zanker, 2018). The original items are generic and it is recommended that they are modified to suit the individual study.

The items were translated to Dutch and modified so that the items assess students' perception of the multidisciplinary STEAM projects. Below is an example of a modified item:

> Original item: ' I would describe this activity as very interesting.'
>
> Modified Item: 'I thought this project was very interesting.'

Although IMI has been used in project-based learning contexts before (Liu et al., 2006), we could not find items for relatedness that matched our context of project-based work in which students interact with clients and professionals in various disciplines. The IMI items are geared towards traditional learning activities. Relatedness questions did not specify persons "I'd like a chance to interact with this person more often". As relations to teammates and clients/experts will be different, both groups were mentioned in the questions:

> "I'd really prefer not to interact with this client anymore"
>
> "I'd like a change to interact with these teammates more often"

New items – inspired by the phrases used in the original IMI - were developed to gain insight on the use of multiple perspectives as this was an important element of this project (item 6, 9, 12, 24, 25, 31). An example is: "I did put a lot of energy in understanding other perspectives."

These perspective-related items will not measure the latent construct of effort, etc. as a whole, but to shed light on how students experience the multidisciplinary aspect of the project.

All items were evaluated by two Technasium teachers and they helped to select the most relevant ones from the IMI and the newly developed ones, which led to a few changes. Furthermore, the teachers proposed items that look into the relation between aspects that foster motivation, see for example an item combining choice and relatedness: "I received confidence from others to perform my duties". All statements were presented using a 5-point Likert scale (1 – strongly disagree, 2- disagree, 3- neutral, 4 – agree, 5- strongly agree). During administration, three items were added later, see table 1 for an overview.

45 RESULTS

45.1 Intrinsic motivation

Half way during the project, 156 secondary students filled in the mid-questionnaire and 136 filled in the post-questionnaire one or two weeks after the project, see Table 1. Of these 92 students filled in both questionnaires. Beforehand, we expected that students might experience the project different halfway the project, then after completing the project. A Paired T-Test using the results of the 92 students who filled in both questionnaires showed that only, four items led to significant differences (Table 2). The students experienced more pressure at the end of the project (item 13 and 14) and their perception on the value of the results (item 8 and 22) increased. This shows that these items – meant to capture competence and value – are influenced by the stage of the R&D process, however, all other items measuring perceived competence and value were not influenced by this stage. Although we do know from the teachers in this pilot and from literature (IDEO 2023; Chiu 2021) that motivation goes up and down during project-work, generally speaking, for these participants, an IMI questionnaire at the middle or at the end of the project, show similar outcomes. Table 3 shows results of all respondents for the mid- and post-questionnaire.

Table 2.
Paired T-test. Items with significant differences (p< 0.10) between mid- and post-questionnaire are shown, n=92.

Themes		**Statements**	**Mid**	**Post**	**Difference**	**95% Conf. Interval**		**Sig***
			Mean	Mean		Low	High	
Perceived Competence	8	I am very satisfied with my performance in this project.	3.39	3.64	.25	-0.453	-0.047	0.016
Pressure	13	I was anxious/nervous while working on the project (R)	1.72	1.96	.24	-0.429	-0.049	0.014
	14	I was relaxed during the project	3.74	3.53	-.21	0.018	0.395	0.032
Choice	19	I did the activities in the project because I wanted to.	3.12	3.29	.17	-0.381	0.033	0.099
Value	22	Our result was useful for the client	3.15	3.42	.27	-0.487	-0.057	0.014

* Significance, 2-tailed

Table 3.
Mean values and standard deviations of the mid- and post-questionnaire.

Themes		Statements	Mid (n=149-156)		Post (n=133-136)	
			M	SD	M	SD
Interest	1	The Design & Research project was fun to do.	3.05	0.84	3.03	1.00
	2	I felt like time flew by when I was working on the project.	2.88	1.00	2.82	1.13
	3	I thought this project was very interesting.	2.87 (n=55)	1.12	3.05 (n=88)	1.00
	4	The project for this client was very interesting.	3.09 (n=55)	0.93	3.17 (n=88)	0.96
Perceived Compe-tence	5	I think I am pretty good at solving Design & Research problems	3.49	0.77	3.45	0.81
	6	I did well in my role as expert	3.33	0.75	3.42	0.79
	7	I think I contributed pretty well at this activity, compared to other students.	3.41	0.73	3.51	0.82
	8	I am very satisfied with my performance in this project.	3.38	0.73	3.58	0.83
	9	I am good in combining insights from different disciplines.	3.46	0.80	3.44	0.74
Effort	10	I did not put much energy in the R&D project (R).	2.32	0.83	2.38	0.92
	11	I have put a lot of effort in this project	3.74	0.77	3.76	0.84
	12	I did put a lot of energy in understanding other perspectives.	3.22	0.78	3.26	0.81
Pressure	13	I was anxious/nervous during the project (R)	1.76	0.79	2.00	0.79
	14	I was relaxed during the project	3.69	0.74	3.56	0.88
	15	I felt pressured during the project (R)	2.33	0.88	2.51	1.06
	16	I was relaxed while conducting the project	3.62	0.85	3.57	0.80
Choice	17	I had a lot of freedom and could make my own choices during the project.	3.58	0.84	3.60	0.89
	18	There were so many possibilities in the project that I found it difficult to get started	2.68	0.89	2.66	0.96
	19	I did the activities in the project because I wanted to.	3.11	0.88	3.27	0.94
	20	I did not have a lot of choice in the way I did things for the R&D project.	2.79	0.86	2.64	0.79
Value	21	I think that doing this activity is valuable for society	3.06	1.01	3.11	1.04
	22	Our result was useful for the client	3.12	0.74	3.46	0.93
	23	I believe that conducting R&D projects is valuable for my future.	3.35	0.99	3.19	1.17
Value	24	I believe that learning to work with different perspectives is useful	3.76	0.78	3.69	0.80
	25	I experienced it as valuable to work from different profiles/expertise's	3.28	0.89	3.37	0.83
Related-ness	26	I felt at ease with my teammates	4.02	0.81	3.83	0.86

Themes		Statements	Mid (n=149-156)		Post (n=133-136)	
			M	SD	M	SD
	27	I'd like a chance to interact more often with these teammates	3.58	0.94	3.43	1.02
	28	I'd really prefer not to interact with this client in the future. (R)	2.86	0.97	2.98	1.00
	29	I had a strong bond with the client	2.21	0.89	2.20	0.89
	30	The experts were very approachable.	2.54 (n=24)	1.06	3.27 (n=63)	1.00
Combined themes	31	I found it difficult to consult with students who think differently from me.	2.16	0.85	2.21	0.90
	32	I received confidence from others to perform my duties.	3.53	0.75	3.45	0.76
	33	My team values my contribution.	3.64	0.82	3.64	0.88

We will now describe the results of the mid-questionnaire only. The intrinsic motivation of the students is on average just above the middle. Approximately 3 out of 10 pupils experience the project as fun and think it is interesting to work for the client. Most students feel competent, on average these items score 3.4. Almost nobody feels incompetent, however, students frequently select the neutral position. The average score for the Effort-items is 3.5 (when reversing the negatively posed item 10), this is higher than their interest-scores. This might indicate that there are external reasons to work on the project.

Students felt in general relaxed, although as indicated before felt a little more pressure at the end of the project. Students did experience choice, this is especially clear from item 17, "I had a lot of freedom and could make my own choices during the project". On the value-items, the average score is 3.3. Almost half of the participants (46%) beliefs that doing an R&D project is valuable for their own future. Learning to work with different perspectives has the highest score.

In general, students felt close to their teammates, see items 26, 27, 32, 33. They received confidence from others to perform their duties and that their team valued their contribution.

The experienced relatedness with clients and experts is less high at first sight. However, the correlation-matrix R showed that items 28 and 29 did not correlate well. A positive response on preferring not to interact with this client in the future does not necessarily mean an low relatedness with the client, it may also indicate that students prefer to do their next project around a new theme. Statement 29 on bonding with the client is probably too strongly posed. Secondary students will not view their relationship with clients in these terms, even when relationships are good. Other items of the original IMI (e.g. could become friends) were also not suitable to measure relatedness. Therefore, we added the statement "The experts were very approachable" later on. Further research on statements to measure relatedness in the context of client-based projects is recommended.

Students thought the project relevant, the score "Our results was useful for the client" significantly increased at the end of the project. They especially thought that learning to work with different perspectives was useful. They thus valued the newly developed multidisciplinary project approach using Jigsaw and other ways of combining different disciplinary perspectives.

Independent T-tests on all items were conducted to compare different groups. Comparisons where made based on study profile, R&D students versus non R&D students, grade and gender. Girls and boys enjoyed the project similarly and felt among teammates almost the same relatedness and interest in the project. A few significant differences were noted, see table 4 on the next page. Only those on pressure were consistently present in both questionnaires. Girls may have perceived a greater value and usefulness of the multidisciplinary projects. No significant differences between the two Nature profiles and the Economic and Society profile were found. The Dutch integrated multidisciplinary STEM projects thus accommodates all types of students. Students in the non R&D track thought the project more fun to do, but these results are not very reliable as these non-R&D track students are from two specific classes and the results could also be attributed to the specific project, client or teacher. Independent T-tests showed that grade 9 scored significantly lower on most of the motivational items (or higher for the reversed formulated ones). Grade 10 and 11 students are more motivated, this could be because after grade 9, students can decide to continue or quit the R&D track, so the more motivated students carry on. More results will be presented at the PATT conference.

Table 4.
Only items with significance (p< 0.05) gender differences are shown. Mean values of the mid- and post-questionnaire.

Themes		**Statements**	**Mid (105 boys, 45 girls)**		**Post (96 boys, 35 girls)**	
			Mean boys	Mean girls	Mean boys	Mean girls
Competence	6	I did well in my role as expert	3.39	3.16		
Effort	10	I did not put much energy in the R&D project (R).	2.45	2.04	2.52	1.89
Presssure	14	I was relaxed during the project	3.81	3.39	3.65	3.31
	16	I was relaxed while conducting the project	3.76	3.33	3.66	3.35
Value	21	I think that doing this activity is valuable for society	2.97	3.36		
	23	I believe that conducting R&D projects is valuable for my future.			3.03	3.63
Combined	25	I experienced it as valuable to work from different profiles/expertise's	3.17	3.56		
Relatedness	28	I'd really prefer not to interact with this client in the future. (R)	2.99	2.51		

45.2 Correlations, factor analysis and quality of the items

McAuley et al. (1989) examined the validity of the IMI and found strong support for its validity, both for a single and multiple factor model. However, this was in the context of sports education and items for relatedness and value were not yet present. As we developed new items, an analysis of the R-matrix and exploratory factor analysis was conducted on all items with more than 130 responses.

The R-matrix shows that the interest-items 1 and 2 correlate with each other (0.54). The interest-items also correlate rather strong with effort. So, interest raises effort and/or vice versa. The interest items also correlate with many of the value-items, the strongest correlation is with *"I believe that conducting R&D projects is valuable for my future*". This confirms that value is related to intrinsic motivation.

The competence-items correlate which each other, but just above the threshold of 0.30, so they either measure different aspects of competence or measure different constructs. The competence items also correlate with items 32 and 33. These two items are part of the set that measure variables in a combined way, in this case how persons perceive how people who work closely with them value their competence. We conjecture from these results that relatedness is relevant in project-work and that the way your team values you and your work maybe stronger than in more traditional education. Further research is needed.

Choice and relatedness interactions are also essential ingredients of project work, and this is also reflected in the newly added item 32. Students should give and receive confidence to each other during an integrated STEAM project, the scores of 3.53 shows that this condition was usually met.

Value was measured in different ways. Items 21, 22 and 23 focus on different external reasons, but still correlate (all above 0.37). The two items relating to the specific multidisciplinary nature of the project (24, 25) correlate slightly (0.30 - 0.34). One could question if one should use items that measure only a part of the value-construct. However, the items show that the use of perspectives and expert roles made the learning activities relevant.

Currently we are still working on the factor analysis using oblique rotation (Direct Oblimin). The Kaiser-Meyer-Olkin measure verified the sampling adequacy for the analysis, KMO = 0.78. However, a clear meaningful factor pattern could not be derived even after omitting problematic items. Quite often, correlations between items of different themes were similar or even stronger than those within a theme. Correlations between items of different themes were also found by (Jones et al., 2018) in the context of Integrative STEAM projects. As the sample size is below 300 and work is in progress, no definitive conclusion can be drawn.

46 DISCUSSION

The Multidisciplinary STEAM projects did not lead to a high intrinsic motivation, even when the need of relatedness in a team was in general met, pressure was low and when students on average are positive about the relevance of the project. The rather low intrinsic motivation may be caused by the low relatedness to the clients. This cannot be derived from the items in the questionnaire, but the open questions at the end of the questionnaire seem to suggest this. In addition, other factors may play a role.

The multidisciplinary approach developed in the Technasium pilot – approaching a problem or question from different perspectives and disciplines – often through Jigsaw- was valued as relevant by many of the students. Students from grade 10 and 11 are more intrinsically motivated, than the younger learners in grade 9. Students who continue the D&T track opt more often for STEM studies (science and engineering) compared to students with a Nature-profile (Blume-Bos, Van der Veen, Boerman 2020).

Vossen et. al. (2018) focused on secondary Dutch Research & Design students as well, found similar scores for enjoyment and anxiety for research projects, but higher scores on relevance than we did. For design projects, enjoyment was higher. Students in the United Kingdom enjoy their technology projects more than our students did, however, it is difficult to explain this difference using self-determination theory as the factors pressure and competence were not very different from the students in our study. Students in Hongkong who followed an integrated STEM projects had a higher intrinsic motivation than the Dutch students especially when their teachers had learned to support choice, relatedness and competence (Chiu, 2021).

Further development of Integrated STEAM projects with clients is needed as well as studies that provide insight in specific teacher strategies and project features that cause enjoyment as well as fulfilment of basic needs.

IMI is a relevant instrument to measure intrinsic motivation and its related factors for integrated STEAM project work with clients, however, items for relatedness need to be developed. Items that combine elements from different factors, shed a new light on motivation of students and are insightful as they show how relatedness in a team may influence perceived choice and competence. More research is needed with improved items and a less diverse group of participants.

47 ACKNOWLEDGEMENT

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49 APPENDIX

Item A:

An overview of the projects and conditions

School	Grade	Theme	Disciplines	R&D track	Jigsaw	Perspectives prompts
1	9	Local Hydrogen Use	Selected by students	yes	yes	Used by Students
2	9	Meat Substitutes	Sociologist/psychologist Nutritionist Marketing Food technologist	yes	yes	Used by teacher
3	9	Repurpose Deserted School Buildings	Selected by students	no	yes	Used by teachers
4	9	Refurbish Conference Room	Technology Social ex Spatial arrangements	yes	yes	No
5	10	Repurposing agricultural buildings	Architect Installation technologist Circular builder Biodiversity specialist Spatial planner	yes	yes	Used by teacher
6	10	Attractive City for companies and living in a relatively sparsely populated province	Geographer Historian Economist Psychologist	no	Unknown	Used by students

8	11	Development of a Skating Rink for the Community	Urban Developer Architect Demographic & historical researcher Ethnographic & Lifestyle researcher	Yes	Different Expert groups	Used by students

Implementing Engineering Based STEM Programs in High School Classroom in the Republic of Korea

Hyuksoo Kwon, Kongju National University, hskwon@kongju.ac.kr
Eojin Kim, Osan Middle School
Jaehoon Jeong, Gyeongsangnamdo office of education Future Education Center
Yubin Lee, Jusan Middle School, youbin8014@naver.com

ABSTRACT

In 2022, South Korea announced a new national curriculum that implement it from 2025. The high school curriculum is about to fully implement the high school credit system, which allows students to choose subjects that suit their needs and career paths. In South Korea, Technology education in middle school is a common compulsory subject, but high school technology education is a selective subject and has the name of technology and home-economics. Secondary technology education experiences difficulties that are not selected in many schools due to the confusion of the identity of subject names and social negative perception of technology. This aims to develop engineering-based integrative STEM education programs that can be used in secondary school technology education and verify its effect on students. To achieve the purpose of this study, an engineering education program was developed and students' changes through the program were measured. This study was based on a single-group pre-test and post-test design and was conducted with 10th grade students. As a result of this study, this study developed five programs that allow students participation-oriented activities. Through the field application research on the program, students improved their attitude toward convergence education and showed high satisfaction. This study provides great implications for actively including and utilizing engineering in technology education. In addition, it will give great implications for the direction and program development of high school technology education.

Keywords: Engineering, High School, Students, Effects, STEM

1. INTRODUCTION

Due to the development of artificial intelligence and the shortening of the expiration date of knowledge and information, the social and economic structures are rapidly changing, and the future is becoming difficult to predict. To adapt to a changing society, the need to develop new competencies such as convergence, creativity, problem-solving, and cooperation is increasing (OECD, 2018). Society needs to transform school education into convergence competency development education that can solve complex problems in the context of learners' lives through self-directed and cooperative exploration, rather than one-sided teaching of fragmented knowledge (Son & Jung, 2019; Kwon et al., 2021).

In line with these educational changes, Korea is promoting the full introduction of the high school credit system by 2025(Ministry of Education, 2021). With the full implementation of the high school credit system, the demand for convergence education (integrated STEM) contents so that students can experience science and technology sites and connect with career education is increasing (Hong, Lee, & Lim, 2022;). It is necessary to develop and distribute class guides and student workbooks that can be applied by in-service teachers by studying the convergence class plan in preparation for the high school credit system and reviewing the effectiveness of the corresponding programs (Woo & Kim, 2019; Kim, 2021; Kim & Hong, 2021; Lee, Yoon, & Yoon, 2022).

The main purpose of this study is to develop a Korean-style convergence education program that can develop the convergence competency that can adapt to the full introduction of the high school credit system and the changes of the future society. In addition, effectiveness analysis will be conducted through the development and application of convergence education (Korea's STEM education) program in relation to representative future occupations that can be used in the high school credit system. Through this study, it is possible to develop a convergence education program to increase students' interest in technology and engineering and provide them with opportunities to explore careers linked to engineering-related subjects.

50 LITERATURE REVIEW

50.1 Convergence (Integrative STEM) Education in Korea

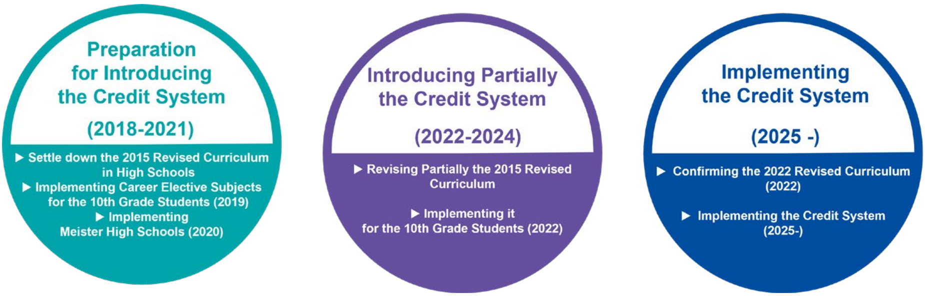
Since 2011, the Korean government has promoted the development and diffusion of STEAM education programs. Currently, it is in the stage of increasing the dissemination and field utilization of convergence class models and programs. First, the government and local education offices have selected and operated leading schools for convergence education and have promoted professional learning community support for teachers' convergence education and school makerspace projects (Baek. et al., 2011; Lee, et al., 2012).

Due to interest in technology and engineering in Korean convergence education, there has been a demand for engineering-focused high school programs. Existing developed programs were found to be too focused on science or mathematics and lacked the flexibility to be used in school settings. To solve these problems, the convergence program should start from a problem situation based on the real life of students. In addition, high school students can improve their attitude toward the field of convergence through a convergence program related to engineering-related jobs (Park. et al., 2012; Jung, Jun, & Lee, 2015; Kwak & Ryu, 2016; Gang & Jin, 2019).

50.2 High School Credit System in Korea

The high school credit system is a new education policy that guarantees learners the right to choose their subjects, allowing students to choose and complete the subjects they want by their career path or interest, and graduate when the minimum achievement level for each subject is met and the required credits are met (Ministry of Education, 2021; Lim, 2022). The implementation plan for the credit system is presented in Figure 1. In 2018, a total of 105 research and leading schools were piloted, and from 2019, it has been expanded to 354 schools and is being piloted. It will be first introduced in Meister high schools in 2020, partially introduced in specialized high schools and general high schools in 2022, and fully implemented in all high schools in 2025(Hong, 2018; Lee, 2018).

Figure 32.
Implementation Plan for the High School Credit System



50.3 Technology Education in the 2022 Revised National Curriculum

With the introduction of the high school credit system in 2025, the 2022 revised curriculum will be implemented, which will restructure subjects focused on student career, aptitude, and competency, and will implement future-oriented instruction and assessments. In the revised curriculum, elective subjects are composed of subjects that allow subject convergence learning, career guidance learning, in-depth learning by subject, and real-life experience learning. Elective courses in high school consist of general electives, convergence electives, and career electives. Among them. convergence elective subjects have been newly established, and their importance has been emphasized as subjects for convergence of subjects within and between subjects, as well as for real-life experience and application(Ministry of Education, 2022a; Gang, 2023).

In the 2022 curriculum, high school technology education is not a compulsory subject, and as a general elective subject, technology subject and home-economics subject are combined and operated under the title of technology and home-economics. There are ‘Robot and Engineering World’ as career elective courses, and ‘General Intellectual Property’ and ‘Creative Engineering Design’ courses as convergence elective courses as Table 1(Ministry of Education, 2022b, Kim, 2023).

Table 16.
High School Technology Education in 2022 Revised National Curriculum.

General Electives	Career Electives	Convergence Electives
Technology & Home-Economics	Robot and Engineering World	General Intellectual Property Creative Engineering Design

'Robot and Engineering World' utilizes basic knowledge in various subjects such as science, mathematics, and information to deepen and expand the content and level of technology, and to understand, design, and manufacture robots, which are representative examples of the convergence of various technologies and engineering. It is a subject that provides an opportunity to solve robot-related problems and at the same time explore various career paths in the world of robot-related engineering (Ministry of Education, 2022b).

The 'Creative Engineering Design' subject experiences the problem-solving process of engineering, understands engineering, explores convergence engineering problems, and learns engineering problem-solving and creative design, which are the basic competencies of engineering. It aims to cultivate attitudes (Ministry of Education, 2022b).

51 METHODOLOGY

51.1 Research Design

The goal of this study is to verify the effect of an engineering-focused STEAM education program applied to high school students on students' attitudes toward STEM, and the research procedure is shown in Figure 2.

To carry out this study, a basic research framework was prepared by analysing previous studies of the STEAM program. The program development team, mainly composed of in-service high school teachers, identified promising future occupations through repeated discussions with the basic research team and developed the program through consultation with external experts. The procedure of program development is shown in Figure 3. The field application team, composed of in-service high school teachers, analyses the effectiveness of the program by pilot-applying the developed program to students in 4 schools.

Figure 2.
Research Procedure

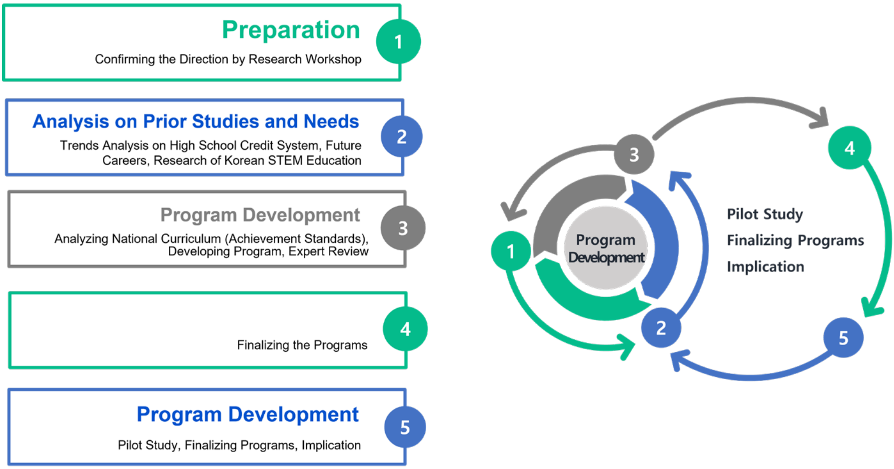
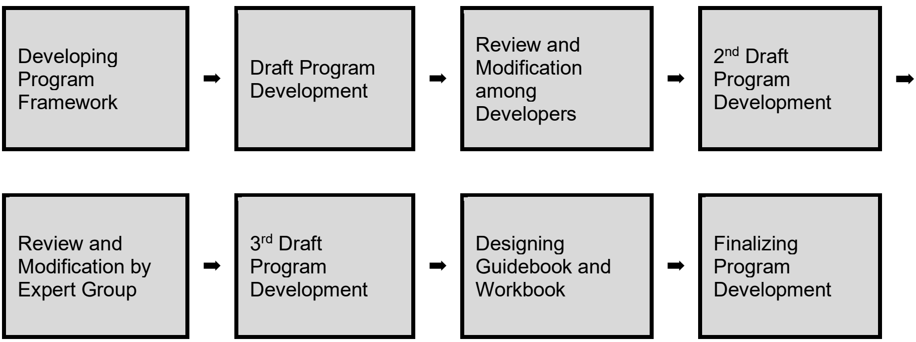


Figure 3.
Program Development Procedure



51.2 Participants

This study was composed of a single group pre-test and post-test design and applied to 900 students from 4 high schools as Table 2. For a single group, the attitude toward STEM was verified before and after the class, and the satisfaction level of the STEM class was investigated after the class.

Table 2.
Pilot studies: Implementation in schools

Program	class time	School	Application period	Main Subjects	Number of students
I am an Expert for Regenerative Energy	6	A High School	9.12.~9.30.	Introductory of Engineering (12th)	100
	8	B High School	8.2.~10.4.	Introductory of Engineering (11th)	41
Dream Comes True: Planning to buy my Own Housing	6	C High School	8.29.~9.30.	Technology &Home-economics (10th)	319
I am a creative tarf designer	6	C High School	8.29.~9.30.	Career (11th)	116
Air and sound pressure fluctuations	4	B High School	9.26.~11.8.	Scientific exploration experiment (10th)	250
Into the World of Data Literacy	5	D High School	8.30.~9.20.	Technology &Home-economics (10th)	100
Total participants					926

3.3. Data Collection and Analysis

An online survey was conducted targeting 900 students from 4 schools participating in STEM classes. This study analysed the data of 691 students who participated in both the pre-test and post-test for the STEM attitudinal instrument. Also, for exploring student satisfaction with convergence education (STEM) class, this study analysed the data of 736 students who faithfully participated in the satisfaction survey after the program ended. Prior to the survey, the purpose of the survey was sufficiently explained to the students, and consent was obtained in advance to conduct an online survey targeting students who wished to participate. The survey was conducted before the program started, and the post-survey was conducted within a week after the program ended.

52 RESULTS

52.1 Program Development

High school credit system STEM programs (Teacher guidebook, student workbook, teacher class PPT, media content materials) were developed. The developed programs were shown in Table 3.

Table 3.
Title and Related Occupation for Final Programs

Program Title	Related Future Occupation

Into the World of Data Literacy	Data Literacy Expert
I am an Expert for Regenerative Energy	Regenerative Energy Expert
Air and Sound Pressure Fluctuations	Airflow Control Engineer
I am a Creative Tart Designer	Camping Business Expert
Dream Comes True: Planning to buy my Own Housing	Financial Expert

4.2. Effects of Korean STEM Education Programs: Students' Attitude

As a result of analysing the data of 691 students from 4 schools who responded both before and after, the student's attitude towards convergence education (STEM) class showed a significant change (t=-56.318, p=0.000). As a result of the overall comparison before and after the attitude test, it was found that student's attitude toward convergence education (STEM) class improved statistically significantly with the application of the program (t=-56.318, p=0.000).
Specifically, there are significant changes in the 'self-direction and reflection' and 'self-concept and efficacy' of the two constructs in the convergence education (STEM) class student attitude questionnaire. This indirectly indicates that students' self-directed learning and reflection took place in this program, and their self-concept and self-efficacy were increased through these convergence education programs. The convergence education (STEM) program developed in preparation for the high school credit system positively improves the attitude of high school students to STEM class learning.

52.2 Student Satisfaction through STEM Class

As a result of the student satisfaction survey, the average of the overall student satisfaction question was relatively high at 3.82, and the students participating in this study were satisfied with all the programs developed.
The item with the highest level of satisfaction in the survey was 'I listened to and respected the opinions of other friends,' with a score of 4.20. This was followed by 'I learned the importance of collaborating with other friends' on 4.12. It is judged that this is because most of the existing high school classes were lecture-type classes, but STEM classes are mostly group activities and discussion/debate activities. In addition, since the developed programs are based on collaboration in the process of generating and selecting ideas, it is a result that meets the intention of the program.
The lowest score was 3.29, which is the item 'I like reading books or articles related to science, technology, and information', which means that the program does not change much in a short period of time because it is a program that is operated in a short period of time at least 4 times and at most 6 times. imply that it was not However, this proves that gradual changes in the above areas can be expected if the program is stably expanded and operated, and continuous support and verification are necessary.

As shown in Table 4, because of analysing the satisfaction level by job, the cooperative attitude showed the highest level of satisfaction. It is recognized that the STEAM class described above requires a cooperative attitude and that students feel satisfaction in the process of cooperation through the STEAM class.

It is judged that the students responded positively to this Convergence Education (STEM) class because there were few opportunities for problem-solving learning and cooperative learning in the entrance exam-oriented education. In addition, since collaboration with peers and communication skills are important in the present and future society in which students will live, the developed convergence education (STEM) program is judged to have led students to have a positive perception.

Table 4.
Students Satisfaction Results for Individual Factor

Factor	Mean	Standard Deviation
Problem Solving and Convergence Thinking Ability	3.89	0.7140
Cooperative Attitude	4.06	0.6922
Challenge	3.83	0.9687
Concern toward Engineering	3.83	0.9687
Attitude toward STEM Subject	3.50	1.0051

53 DISCUSSION

The developed program can be used in a variety of subjects by field teachers aiming for convergence education (STEM) classes within the high school credit system, which will be fully implemented in 2025. In addition, it is expected that it will provide opportunities to contemplate the changing aspects of the world of work and become creative problem solvers. In addition, based on practical experience and data on models and assessment methods for convergence classes, student participation-centered STEM instructional models and assessment methods will be created. This program is expected to have a positive effect on the conviction of convergence education based on its high field applicability.

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Professional Learning Opportunities for the Hangarau Māori-medium Technology Curriculum

Ruth Lemon, Waipapa Taumata Rau, University of Auckland, ruth.lemon@auckland.ac.nz

ABSTRACT

This paper is the third in a series of papers exploring the development of the Māori-medium Technology curriculum, specifically focusing on professional learning development. It utilises document analysis and interviews with curriculum experts, drawing on curriculum alignment and coherence theories. Curriculum coherence affects student learning across various levels: national, subject, school/classroom, and systems. Data comes from Ministry of Education records and interviews with teacher professional development facilitators. The study reviews professional learning literature, particularly meta-analyses and reviews, in the context of curriculum coherence. It examines how curriculum coherence relates to the professional development needs of teachers implementing the Hangarau curriculum, highlighting the challenge of interpreting broad learning outcomes. The paper suggests principles for aligning national curriculum content and professional learning, aiding facilitators and teachers in designing effective professional development for improved student learning.

Keywords: Hangarau, Māori-medium Technology, curriculum coherence, indigenous Technology, Technology curriculum.

1. INTRODUCTION AND CONTEXT

Internationally, the field of education has witnessed significant changes in the conceptualisation and implementation of professional learning over the past few decades (Alton-Lee, 2017; Ewing, 1970; Murphy et al., 2009; Wylie, 2012). New Zealand's political and education system is generally highly influenced by international trends including how professional support is provided to teachers, particularly so in the past 30 years. For example, prior to the 1980s, there was no centralised model for providing professional learning to teachers in support of government education initiatives. In-service training, as it was known then, was a voluntary in-service training system that aligned with a cascade approach (Timperley et al., 2007). Various forms of training were available, such as seeking assistance from a limited number of advisors, utilising video services that demonstrated pedagogical approaches, or participating in collaborative development at Lopdell House (NZCER, 2013; Wylie, 2012).

External experts trained school leaders who then disseminated the learning to teachers within their schools. However, this model gradually evolved into a coaching and mentoring approach

(Robertson & Murrihy, 2006), where selected teachers received external training and then shared their knowledge with colleagues upon returning to their schools.

Internationally, during the 1980s and 1990s, the narrative associated with in-service training underwent a transformation, highly influenced by neoliberal ideology (Wylie, 2012) with professional development and professional learning becoming the preferred terms (Ministry of Education [MoE], 2023; OECD, 2022), The shift towards neoliberalism brought about changes in the way teacher professional development was conceptualised, funded, and delivered. Neoliberalism encouraged a more targeted approach to professional development. Schools were expected to identify their specific needs and invest in professional development programs that directly addressed those needs (Lee, 2000). This shift reflected a broader understanding of professional growth, emphasising continuous learning, collaborative engagement, and empowering educators to take ownership of their development (Bonne & Wylie, 2017; Timperley et al., 2007). Funding for teacher professional development became increasingly tied to a schools' performance outcomes, with a focus on demonstrating improved student achievement (Day et al., 2016)

The change in terminology also highlighted the recognition that professional growth encompasses both the acquisition of new skills and knowledge and the development of attitudes, beliefs, and values that support effective teaching and learning (O'Brien & Jones, 2014). These changes were driven by advancements in educational research, infrastructure, and policy, leading to a decentralised approach to professional development in New Zealand, where individual schools took responsibility for supporting their teachers' professional growth (Education Act 1989; Lee, 2000; Rishworth, 1996).

The professional development model(s) and policies which have underpinned schooling in New Zealand generally have also been applied to Māori-medium schooling, despite the considerable capacity differences between the two models (Lemon et al., 2020, 2023). For example, there has been a transition toward centralising the funding and prioritisation of professional learning at a national level (MoE, 2023), still optional, not mandatory (OECD, 2022). Consequently, this transition has created a tension between a centralised approach driven by national policies and the need for personalised learning to meet local and diverse learner needs. This issue of balancing standardisation and customisation forms the problem space for this study, specifically focusing on lack of support of professional development for the Māori-medium schooling sector to support the successful implementation of the hangarau curriculum. This points to the lack of understanding at the policy level of curriculum coherence. Curriculum coherence refers to the alignment and consistency within a curriculum framework or across different components of an educational system (Sundberg, 2022). It ensures that the various elements of curriculum, such as goals, content, assessment, and instructional strategies, are logically interconnected and work together effectively to support student learning. The concept of curriculum coherence is important in providing a unified and meaningful educational experience for students. There are several levels of curriculum coherence, each addressing different aspects of the curriculum. The level of concern to this paper is the implementation of curriculum via professional learning. Curriculum implementation concerns the enactment of the curriculum in classrooms (Lemon, 2019; Lemon et al., 2023; McMurchy-Pilkington, 2008) The alignment between curriculum objectives and instructional practices is crucial for successful implementation (Wiggins & McTighe, 2005). This paper argues that curriculum coherence has not been fully achieved in supporting the implementation of the hangarau curriculum. Thus, its implementation has been extremely variable across the country. This paper proposes a theoretical framework to address curriculum coherence issues in Māori-medium schooling that may have applicability to other minority indigenous communities.

The methodology will be briefly outlined, followed by the discussion of a framework that presents an initial set of principles that support curriculum implementation for indigenous Māori-medium schools and recommendations for further research. By addressing the issue of curriculum coherence, this study aims to contribute to the improvement of professional learning practices in Māori-medium contexts and potentially other similar marginalised indigenous language education contexts.

The main research question for this paper focuses on the relationship between the indigenous philosophy of Hangarau and Professional Development for Māori-medium schools. This paper also explores the place and role of indigenous Māori knowledge in Hangarau. What are the ways in which the content, design and structure of professional development opportunities acknowledge, and reflect indigenous knowledge, and pedagogy of the marau (curriculum)? What are the implications these concepts have on classroom implementation and the enactment of the marau Hangarau?

55 BACKGROUND

Technology is a relatively new discipline in schooling, having emerged as a standalone subject in the 20th Century (Jones & De Vries, 2009), thus, much of the literature on professional learning is more generalised. However, the definitions of professional learning are diverse, ranging from: professional learning development; continuing professional development; teacher development; in-service education and training; staff development; career development; continuing education; to lifelong learning. The broadest definition posits that professional learning incorporates "any experience of educator learning" (Netolicky, 2020, p.5) "during the course of a career" (Day & Sachs, 2004, p.3), including both formal and informal learning opportunities (Bolam & McMahon, 2004; Bubb & Earley, 2007; Day, 1997; Earley & Porritt, 2010). Researchers have extended this definition by including the notion of design, that these professional learning experiences have been crafted and differentiate between traditional and innovative delivery of these learning experiences (van Veen et al., 2012). In contrast, other definitions focus on the need for this learning to have a positive impact on students in the classroom (Scales et al., 2011). In the New Zealand context, Wylie (2012) traces the common usage of the term – in-service education, to professional learning, to professional development, as carrying within the term an evolving notion as to the nature of what it means to be a professional engaging in on-going learning.

As with the definitions of professional learning, there are a range of categories or types of professional learning models and/or frameworks that have been identified in the literature. Notable are, the exploration of functions (extension, renewal and growth) and drivers (systemic and personal) of professional learning in the Australian context (Grundy & Robison, 2004); the identification of a baseline to facilitate the measurement of impact in continuing professional development in London (Earley & Porritt, 2010).

One of the issues that has underpinned professional learning is the issue of focusing on deficit learning and/or thinking (Netolicky, 2020; van Veen et al., 2012). Deficit thinking, also known as a deficit perspective or mindset, is primarily associated with education and professional development. It refers to a negative and limiting approach that focuses on identifying and addressing the weaknesses, shortcomings, and deficiencies of individuals, especially students or professionals, rather than recognising and building upon their strengths and assets. Approaches based on deficit thinking tend to be reactive and focused on remediation rather than prevention and proactive development. This can result in temporary fixes that don't address the root causes of issues. To address these issues, it's important for educators, trainers, and professionals to shift their mindset from a deficit perspective to an asset-based perspective. This involves recognising and valuing the diverse strengths and assets that individuals bring to the table, fostering a growth mindset, and providing support and resources to help individuals reach their full potential. An asset-based approach can lead to more inclusive, motivating, and effective learning and professional development experiences.

A more specific tension lies in the scarcity of professional learning opportunities that are targeted to the Māori-medium context in Aotearoa (Marshall & McKenzie, 2011; Murphy et al., 2009). A 'one size fits all' approach has resulted in English-medium content being delivered with Māori-medium practitioners and a majority of research that is conducted with a focus on the New Zealand Curriculum (Alton-Lee, 2017; Bonne & Wylie, 2017; Hipkins & McDowall, 2020; Timperley et al., 2007). There is the associated need for a significant increase in the support given to Māori-medium teachers, in terms of second language acquisition theories and pedagogies (Marshall & McKenzie, 2011; Matamua, 2012).

56 METHODOLOGY: CURRICULUM ALIGNMENT THEORY

This section provides an overview of the research methodology and the data for this study. This paper builds on an earlier study that focused on the first two iterations of the Hangarau curriculum document between 1999 and 2008 (Lemon, 2019; Lemon et al., 2022). This paper concentrates on professional learning in relation to the implementation of the hangarau curriculum.

As argued, curriculum coherence is critical because it enhances the quality of education, improves student learning experiences, and supports educators in their instructional efforts (Sullanmaa et al., 2021). It aligns curriculum components, ensures a logical progression of content and skills, and ultimately contributes to the overall effectiveness and equity of the education system. Curriculum coherence underpinned by curriculum alignment theory emphasises the importance of aligning curriculum components such as learning objectives, instructional materials, teacher professional development and assessments to ensure a cohesive and integrated educational experience. It helps to reduce the disruptions between the intended process and the actual process (Wenzel, 2016). Roach et al. (2008) defined alignment as "the extent to which curricular expectations and assessments agree and work together to provide guidance for educators' efforts to facilitate students' progress toward desired academic outcomes" (p.160). This implies that curriculum alignment plays a large role in ensuring consistent and robust curriculum delivery across the school, thereby improving the quality of students' school experience.

56.1 Method

There were two sources of data. The first was secondary data collection which involved a series of information requests to the MoE under the Official Information Act 1982. The MoE is the agency primarily responsible for teacher professional development in New Zealand. The Professional Learning Development (PLD) documents (both first and second tier) covered in the dataset included: Contracts; schedules of payment; milestone reports; discussion documents; workshops; cluster meetings' minutes; surveys; school submissions and proposals (MoE, 1999-2000a; 1999-2000b; 1999-2003; 1999-2008; 2003-2012; 2007-2009; 2008-2010). Several PLD projects that were documented included a range of PLD opportunities, between 1999 and 2012, that embody key thinking about PLD at that time.

The second data source were interviews with experts, or mātanga who were involved in the development and/or implementation of the Hangarau curriculum. In the indigenous Māori context, mātanga are considered experts in a particular field. In this case, it refers to experts with a teaching background, who have worked in the design and implementation of Professional Learning and Development (PLD) opportunities with teachers. Mātanga is a recently coined term used to represent someone who is an expert in these disciplines. The mātanga that agreed to participate chose a time and location that was convenient for them. The semi-structured interviews were approximately an hour in duration. The interviews were recorded and transcribed prior to coding and analysis.

Interviews were conducted with the five mātanga. Their views of the development of the Hangarau curriculum (MoE, 1999, 2008, 2017a) with respect to the development of professional development and learning opportunities for educators are discussed after the mātanga are introduced below.

Mātanga tuatahi (M1) from Northland, was given responsibility for the management of the re-design of Te Marautanga o Aotearoa in 2004. M1 had over a decade of teaching experience within Māori-medium settings that informed M1's practice. M1 has led capability training and the design of curriculum support materials for 18 years. Mātanga tuarua (M2) from Northland initially worked as part of the team writing the Science curriculum in the 1990s. M2 led the development of the inaugural Hangarau document in the 1990s and has since transitioned to focusing on work in curriculum design, PLD and the development of curriculum support materials to the Marautanga Pūtaiao (Māori-medium Science Curriculum). Mātanga tuatoru (M3) from the East Coast had teaching experience in English-medium contexts, in both Aotearoa and the UK, before working with colleagues in establishing a bilingual unit. Experience across the levels, working with six-year-olds through to secondary school students, and having a strong network of educators, led to this mātanga being part of the advisory group in the development of Science, before heading the development of Pāngarau in the 1990s. Subsequently, M3 led the re-development of the front section of Te Marautanga o Aotearoa and worked across the curriculum in the standardisation of the lexicon. All these mātanga are involved in the curriculum refresh which started in Aotearoa-NZ in 2021.

Mātanga tuawhā (M4) from Taranaki and Wellington, was initially part of the curriculum development team for the Technology curriculum (commonly known as the choccie doccie) before joining the writing team for Hangarau. M4 worked as a Hangarau Facilitator before working as a kura kaupapa Māori principal for the next 22 years. Mātanga tuarima (M5) from Hawke's Bay has been involved in Hangarau as a PLD facilitator, a regional coordinator and as a designer of second tier (or curriculum support materials), since 2000. M5's focus has been on ensuring that there are resources that classroom teachers can use in their exploration of and engagement with the Hangarau curriculum. M5 was a member of the reference group in the addition of the Hangarau Matihiko (Māori-medium Digital Technologies) content to the Hangarau curriculum (MoE, 2017a).

56.2 Coding and data analysis

The dataset, the documents and the interviews, were coded and analysed using in-vivo coding (not the application NVivo, the concept of drawing out the codes where they lie, using the words of the dataset to define the codes) for the first-cycle of coding, and then focused coding for the second-cycle of coding (Saldaña, 2022). Analysis was conducted through an adapted approach to thematic analysis (Braun & Clark, 2006; Guest et al., 2012; Thomas, 2006). The findings have been summarised very briefly in the next section.

57 KEY FINDINGS

Initial in-vivo codes were generated for the complete dataset, then a second cycle of focused coding was conducted. An outline of the synthesis in relation to Professional Learning Development (PLD) is discussed below. Table 1 shares an outline of the key Hangarau PLD opportunities that were detailed in the documents and then each of the following notions identified as being a significant notion related to PLD from the dataset is outlined briefly.

Table 17
Key Hangarau PLD Opportunities

Date/Year	Region	Participants	Professional Learning Development description	Request #
1998-2000	National, school-based with facilitators working with 4-5 kura at a time.	114 teachers participated in the PLD run by Massey University in 1998.	3 contracts (1 year initially, but extended to 2 years) including a range of PLD opportunities.	1214766, 1223652 and 1207583
Nov 17-19, 1999	National 3-day hui convened at a hotel in Rotorua	40 participants from multiple schools	National Hangarau conference: seven keynote speakers and four workshop sessions.	1139624

2000	Auckland/ Northland regions	Whānau attended with teachers, due to the central role that family play in kura kaupapa Māori.	Series of wānanga and night hui run by Te Haeata Trust, implementing two proposed models of staggered delivery, with in-class support.	1223652
2000-2001	Waikato and Northland	4 schools in each region.	Series of hui and in-school support, coordinated by Te Tihi Ltd.	1214766
2003-2005	Targeting teachers from different regions in each iteration of the programme.	10 teachers accepted into each block. Two extra places available for Resource Teachers of Māori and Māori Advisers.	Te Whakapiki Reo Hangarau: An intensive 20 week programme providing curriculum support in hangarau, delivered in the medium of te reo Māori. Content included second language acquisition strategies, curriculum coverage, and assessment practices for hangarau.	1214766 and 1207583
2012-2013	14 kura across four clusters: Northland, Waikato, Central North Island, East Coast.	Initial scoping completed, but project was not completed.	Beacon Practice Technology Project phase three aimed to include Hangarau in providing in-school coaching, modelling and mentoring to enhance classroom practice.	1214766

Prior to the inaugural development in the 1990s, there was a significant paucity of research which examined the development and implementation of Hangarau. This meant that curriculum developers and professional development facilitators did not have a research base to inform their decisions (Mātanga 1, 3; 4, 5; MoE, 1999-2000a; 1999-2000b; 1999-2003; 2003-2012). This significantly impacted on the design of the first Hangarau curriculum development, particularly in the 1990s when by default the Māori-medium version was a translation of the English-medium version. However, the paucity of research was addressed in the second iteration when the need for research was recognised and written into the contracts for the curriculum developers working towards the second iteration of Hangarau, although the existing literature had been written for the Technology curriculum (Mātanga 2; 5; MoE, 1999-2000b; 1999-2008; 2003-2012). Finally, it impacted on the development of PLD opportunities: in the 1990s, the cascading model (Timperley et al., 2007) was the most common model being implemented, with teachers being withdrawn to experience the learning, and then returning to their schools to share their learning and include it in their classroom practice (Mātanga 1; 4; 5; MoE, 1999-2000a), also referred to as the Individual Teacher Model (MoE, 1999-2000b). Aside from the challenges of being the sole teacher at that school that had learning to bring back and share with your colleagues – the PLD facilitators were also challenged in trying to ascertain the best content to deliver. It was not long until professional learning was being designed to run in schools, the whole school development approach, and allow for peer mentoring and teaching utilising more of a wānanga (the advancement of knowledge, development of intellectual independence, and application of knowledge regarding Māori traditions according to Māori customs) approach (MoE, 1999-2000a; 1999-2000b). By 2012, the whole-school coaching, modelling, mentoring approach had been identified as a potentially effective model for Māori-medium, although it was also noted that it had been 8-10 years since some teachers had engaged with any PLD around Hangarau (MoE, 2003-2012).

57.1 Summary of key findings

There were five key findings that have been outlined in this section: The relationship between PLD and teacher retention; between the small pool of experts and discerning whether facilitator concerns are shared more widely; the imbalances in the sector, with more working at lower levels of the curriculum, and more females than males delivering hangarau content; language acquisition as a key focus of PLD; and the importance of developing tailored PLD for teachers engaging with the Hangarau curriculum.

First, Ogilvy (2012) analysed the 2000-2011 payroll data and found that 70% of Māori-medium teachers were leaving the class within their first three years as opposed to 30% of English-medium teachers (although the former may potentially be a higher figure) which is of considerable concern. Early career teachers bring fresh perspectives, enthusiasm, and up-to-date training to the profession. When they leave prematurely, schools lose valuable talent and expertise that could have contributed to the improvement of education. Teacher stability is linked to the quality of education. Schools with a stable and experienced teaching staff often perform better academically and provide a more positive learning environment. The only way to identify Māori teachers is by looking for those teachers that are paid a MITA or Māori Immersion Teacher Allowance, which is a scheme that teachers need to enrol into). Simple solutions were proposed in the dataset, ranging from simple acknowledgement through regular contact, either in the form of an email or a quick phone call (MoE, 1999-2003) to exploring ways in which the development of curriculum support materials could be developed as part of a proposed PLD programme (Mātanga 1; MoE, 1999-2000a; 2003-2012). A retention pilot programme (Wehipeihana et al., 2018) found that, with the appropriate supports built in to support beginning teachers, there was a marked improvement in retention, with only 20% of teachers leaving the classroom within the period in which these pilot programmes were running. A submission to Professional Learning Aotearoa New Zealand from Māori-medium PLD providers (2014) shared that they were experiencing much higher losses with the schools they were engaging with – as 70% of provisionally registered teachers were leaving Māori-medium schools by their third year of teaching, which confirms that this issue, although variable, is ongoing. The findings of Wehipeihana et al., 2018, suggest that PLD can be used as a supporting mechanism, particularly for beginning teachers.

Second, the small pool of hangarau support people makes it difficult to tell whether facilitator concerns are representative / shared nationally (Mātanga 3; 4, 5; MoE, 1999-2003). This tension holds true when considering the development of curriculum support materials, or the development and implementation of Professional Learning opportunities. It is also difficult to ensure that the appropriate expertise is available for the duration of the project as there is a very small pool of experts with the appropriate discipline knowledge and associated language competence (Mātanga 1; 2; 3; 5; MoE, 2003-2012; 2007-2009; 2008-2010). Creative solutions have been applied across the board – where colleagues share the load, transferring the role of lead writer briefly, to ensure deadlines are met (Mātanga 5; MoE, 1999-2008). It is also noted that it is important in any development for Hangarau, that it is important to name the whakapapa or genealogical connections of all of the mātanga, as this will define the contexts in which the development is happening (MoE, 2003-2012).

Third, it is difficult to find practitioners working across the various curriculum levels, particularly levels 5-8 (secondary school, students aged 13-18 years). Again, this is across the board, including the tauaromahi or exemplars project (Mātanga 4; 5; MoE 1999-2003), the raweke ira curriculum support materials (MoE, 2007-2009), and other support materials aimed at levels 5 and 6 of the curriculum (Mātanga 1; Mātanga 2; Mātanga 3; MoE, 1999-2008; 2008-2010). There is also a gender imbalance (Mātanga 1; Mātanga 5; MoE, 1999-2003), with larger numbers of female practitioners available, resulting in two key impacts – the imbalance in societal representation; and the tendency for women to not work with drills and lathes.

Fourth, and related to one of the key goals across Māori-medium educational contexts, that of language revitalisation. The language associated with the Hangarau curriculum is important. Curriculum support resources (MoE, 1999-2003; 2007-2009) and PLD opportunities (Mātanga 1; Mātanga 3; Mātanga 5; MoE, 1999-2000a; 1999-2000b; 2003-2012) need to consider the language that is being used and what supports are needed to ensure that both teachers and students will be able to engage with the language in the classroom context. With the advent of kura-ā-iwi (tribal schools) in 2011, there is an accompanying recognition of the importance of dialectual language and localised knowledge.

Fifth, the concept of mana ōrite or equal status is fairly new, and the disparity between the budget allocation for Māori-medium as opposed to English-medium has not been completely negated. There is less time, less money, and less resourcing generally for Māori-medium teams that are meeting the same outcomes as their English-medium counterparts (MoE, 1999-2003; 2008-2010; Mātanga 2; Mātanga 4; Mātanga 5). If the aims expressed in various policy documents (MoE, 2013; Te Puni Kōkiri, 2019) are to be realised, it will need to be resourced. The sector cannot grow until it can become a first choice for any Māori whānau in the country. This tension has contributed directly to potentially successful PLD programmes finishing early (Mātanga 2; MoE, 2003-2012) – how can we ensure that when working with English-medium colleagues, that a balance is maintained – that mana ōrite is honoured and that Māori-medium components do not become second-grade citizens of the complete PLD package? It is important to note here, that the intentions appear to have been honourable:

> R____ advised that the implementation of the Beacon Practice Phase 3 Hangarau project (particularly given the way hangarau tends to be integrated in a range of other learning areas from years 1-13), needs to be tailor-made to suit Māori medium contexts. Because the needs and contexts of English and Māori medium (including the curriculum documents) are quite different, R___ advised that separate strands for each medium would be best. (p.2, doc 8 of series)

In Schedule 1 where the description of services is being outlined by the MoE, it continues:

> The initial scoping work (covered by this contract) is intended to identify if a BPH project should be undertaken and provide guidance on how a BPH project should be undertaken, should it be conducted. The scoping exercise will look at ways to help grow

the quality of student learning experiences in hangarau through providing support that is tailor-made to suit Māori medium contexts. (p.3, doc 9A of series).

58 DISCUSSION: SOME INITIAL PRINCIPLES FOR HANGARAU PLD DESIGN

The principles outlined in this section were developed as a result of the important considerations identified in the literature. Particularly significant are the ideas that professional learning should originate from an assets-based perspective and the call to address the scarcity of professional learning that has been developed specifically for the Māori-medium educational context (Marshall & McKenzie, 2011; Murphy et al., 2009). The analysis of the dataset and the resulting five notions that were outlined briefly above have been used in the development of key principles to consider in the design of professional development for Māori-medium educators, and specifically for the Hangarau curriculum. The initial principles are as follows:

(i) Professional learning for small, limited capacity communities should be bespoke, not one size fits all. A lot of the content currently being delivered to Māori-medium educators is not targeting Te Marautanga o Aotearoa.

(ii) Needs to be strength-based not deficit.

(iii) Professional learning should be delivered bilingually and should be designed using a te ao Māori lens (Murphy et al., 2009). If Māori-medium is to claim the right to indigenise Hangarau, and other Wāhanga Ako (Learning Areas, or disciplines), then it needs to be given the opportunity and the space to develop Hangarau without its design being determined by the needs of the English-medium sector. The Māori-medium sector should determine their educational needs.

(iv) A lot of the literature identified principles that could be helpful – if applied in specific ways. i.e., longer periods of time are helpful, as they allow professionals time to engage with the new thinking. Professional learning needs to be differentiated, looking at appropriate delivery mechanisms – andragogical approaches as an example – because the development is being delivered to adult learners (Knowles et al., 2020), allowing for co-construction of development aims, buy-in and engagement from the teachers choosing to engage with this specific opportunity. There has been a move from a cascade approach, coaching and mentoring, to acknowledging the important of a community of learners, that may transcend the single school unit.

(v) There needs to be a balance of formal and informal opportunities, where there is the opportunity to discuss, model, observe, be active in knowledge-building, where teachers get the opportunity to take what they've learnt, practice it with their students, and then return to the group, sharing their feedback and feedforward: How did the innovation work in their classroom? What could they do to further innovate with their students?

(vi) Current teachers require training, as do the next generation of teachers, and teachers returning to the sector from overseas or a break in teaching, therefore, PLD must be ongoing.

- If we are to consider the imbalance between demand and supply – the small pool of mātanga and Hangarau practitioners with the requisite skills and the corresponding requisite fluency in te reo Māori – we need to develop online materials that can be engaged with asynchronously, or that kāhui ako (learning clusters, groups of schools that are generally geographically close to each other, that can choose to work together in collaborative professional learning opportunities) can engage with together (One of the caveats of working with asynchronous material as a busy professional, is that it is challenging to make the time to engage. This can be mitigated if you work through the asynchronous materials as a collective).

(vii) Theories and rationale that are being used to determine professional learning models should be informed by systematic research in Māori-medium contexts. In 2012, the MoE was contracting Pauline Waiti to consult with the sector and to develop a model that would be most efficient for Māori-medium contexts (MoE, 2003-2012). The outcome of the Hangarau Beacon Project was not available in the materials that the MoE had available about the Marautanga Hangarau but the author was told confidentially that this research had been cut short due to political reasons.

59 INITIAL CONCLUSIONS AND FURTHER RESEARCH

There was an unexpected gap in the literature, in that a history has not yet been written focusing on the evolution of PLD in Aotearoa-New Zealand. Wylie (2012) and NZCER (2013) were used to read around the edges of the gap, as Wylie speaks of some of the developments in the field, in relation to her focus on the transition to schools as self-managing units. Evaluations of specific initiatives conducted by Māori researchers was helpful in reading around part of the gap (i.e., Marshall & McKenzie, 2011; Matamua, 2012; Murphy et al., 2009) and a series of professional conversations with colleagues filled in the rest of the blanks – but it would be recommended for a complete history of PLD in both the English-medium and Māori-medium educational sectors in New Zealand would benefit the next generation of professional development facilitators. There was a related challenge getting access to MoE documentation that impacted and directed curriculum development and associated implementation support to critique coherence issues.

Effective ongoing PLD is argued as vital to best practice (Lemon et al., in-press; Fowler, 2012; Murphy et al., 2009; Robertson & Murrihy, 2006; Timperley et al., 2007, 2008). Research must be conducted in a range of Māori-medium contexts to evaluate what is most effective for Māori-medium educational contexts and to evaluate the principles of best practice for the Māori-medium sector. It is expected that the number of experts and schools will grow as Māori-medium education grows and becomes the first choice of education for their children and grandchildren. The sector needs to grow to reach a critical mass to ameliorate the challenges of designing professional development for teachers in the area (and indeed, the challenges of curriculum implementation).

The PLD documentation also identified a gap in the primary sector. From the early documentation, through to the Hangarau Beacon Project in 2012-2013, it is evident that there is significant diversity in pedagogical approaches to teaching and learning Hangarau, including a range of problem-centred, constructivist and sociocultural pedagogical approaches based on a foundation of mātauranga Māori. Despite this diversity, Māori-medium contexts have a commonality in the use of local knowledge and kōrero tuku iho (history through oral tradition) to provide a context for Hangarau practice. This use of local/place-based knowledge "grounds the teaching and learning programme in the kura's locality and the associated whakapapa (genealogical connections) and is reflected in the marau-ā-kura (local curriculum) that many of them have developed" (MoE, 2003-2012, p.20).

There is a need to establish coherent systems at various levels that will preserve, update and be responsive to the curriculum support materials and PLD needs for Māori-medium settings. This may be in various forms –blended models for PLD: asynchronous and face-to-face components. Successive governmental administrations have invested in Hangarau – however, this investment needs to be ongoing and available long-term. Ethically and culturally the work of others needs to be valued and retained – not thrown away at a set date. When data is collected and resources made, provisions should also be made for the longevity of the resource – for future generations. We need to look back to move forwards.

The recurring challenges across the domains of curriculum development and implementation indicate a need for increased investment in the need to ensure coherence. Without this increased investment, the cycles of shortages will continue including shortages in the number of experts who are fluent speakers of te reo Māori; shortages of schools that can participate in trialling, development and review of either curriculum documents or curriculum support materials.

Hangarau has consistently been identified as a curriculum area that holds great potential for cross-curriculum teaching and learning yet there have been significant misconceptions about the curriculum since its inception, and it continues to be underrepresented in the taught curriculum. A common misconception is that Hangarau is synonymous with devices or high technology. Hat is, people commonly say, 'Hangarau is educational technology, equating with the use of educational technologies'. It is not. Hangarau is strongly connected to the place, providing many opportunities for teachers and schools to research, reclaim and reframe localised indigenous knowledge. As an emerging discipline, Hangarau needs further research, more support materials and PLD opportunities to facilitate an increasing interest in the field and the future growth of the discipline as one that can be studied from early childhood to the tertiary level.

An important question for education policymakers is whether attending to curriculum coherence leads to meeting the needs and fulfilling the aspirations of the Māori-medium education community. The sector argues that more autonomy and self-determination are vital to Māori-medium schooling, where the communities that hold the knowledge should have a say in resource priorities. Likewise, Māori communities need to be the ones who make the decisions about where this information is stored and who gets access to it. He ao te rangi ka uhia, he huruhuru te manu ka rere. The world is covered by the sky, it is because of feathers that a bird can fly. The Māori-medium sector, with all of its complexities, needs to have autonomy and self-determination to be able to continue the processes of indigenisation. The sector needs investment to grow and to break the cycles of problems and issues that have been ongoing for the last thirty years. This investment will allow the sector to fly.

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Rupe Rere Nui: Place-based Storytelling in Robotics with Māori-medium Students

Ruth Lemon, Waipapa Taumata Rau – University of Auckland, ruth.lemon@auckland.ac.nz
Craig Sutherland, Waipapa Taumata Rau – University of Auckland, cj.sutherland@auckland.ac.nz
Allan Fowler, Waipapa Taumata Rau – University of Auckland, allan.fowler@auckland.ac.nz

ABSTRACT

This paper is part of a larger study involving the design and implementation of a prototype of a low-cost programming environment or tangible user interface (TUI) where students use robots to navigate a geographical map in telling and re-telling stories associated with that place. The geographical map that was initially developed depicted the Wellington region (the lower North Island of New Zealand), as the lead researcher for this project had connections to Wellington. The story-telling focused on the narratives of Kupe, a Māori explorer and one of the first to discover New Zealand. However, in response to an inner-city Auckland school, we designed a map that would support the children's engagement with local landmarks, as expressed in a waiata (song) called *Rupe Rere Nui*. Māori kaumatua (elder), Wally Penetito, exhorts teachers to 'start where your feet are', emphasising the importance of place-based learning or localised curriculum.

This paper's focus lies in an unexpected research outcome and the resulting **pedagogical possibilities**: the importance of responsive curriculum design when you are working in classroom contexts. The study contributes to the field of localised curriculum with a focus on the place of storytelling and the incorporation of non-technical subjects, such as place-based narratives, into a robotics system. The use of paper-based commands with young children aged between 5-9 years of age has been evaluated over a range of settings and the working prototype has been refined as a result of trials with teachers and children in classrooms.

Keywords: place-based education, local curriculum, screen-free robotics.

1. CONTEXT AND INTRODUCTION

This paper is part of a larger study involving the design and implementation of a prototype of a low-cost programming environment or tangible user interface (TUI) where students engage with geographical maps, as they programme their robots and tell them which locations to visit, telling stories associated with that place (Naude et al., 2023). The focus of this paper is on an unexpected outcome from the research, that may lead to further study. One of the classes in one of the schools that we visited, inner-city Auckland students in a Māori-medium educational context, decided that they would like to develop their own map and focus on the major landmarks around their school.

60.1 Definitions

Connotations and denotations of terms can be very subjective and a single term can hold a range of meanings. Key terms in this research that require definition include: Māori-medium; place-based learning or localised curriculum; computational thinking; hangarau or technology; and young children.

The Māori-medium education sector in Aotearoa New Zealand originated as a series of community initiatives as direct challenges to the previous century and a half of colonisation and the English-only language policy that had been implemented in the education sector. So Māori-medium students are those who are enrolled in classes where over 50 percent of their learning is conducted in te reo Māori (Māori language) with mātauranga Māori (Māori knowledge) as the foundational knowledge-base for all teaching and learning in these educational contexts which range from kōhanga reo for babies, toddlers and very young children, through to whare wānanga, or institutions of higher learning for adult students. This paper will focus on students who are part of a specific whānau rumaki reo (an immersion classroom set within an English-medium school), which is one type of Māori-medium schooling for children aged between 5 and 12 years of age.

Place-based learning or localised curriculum is a blanket term encompassing the range of pedagogical practices that focus on learning about and connecting to place (Yemini et al., 2023). This concept of place transcends geography, the physical context of place, and includes the experience of the individual in that place; the group(s) of people that connect to and are in relationship to that place; and external impacts on the concept of place (such as economics and politics; see Ardoin et al., 2012 for a breakdown of a leading framework for place-based education). A recent framework breaks down the dimensions of place-based education as consisting:

- Learning in place (where just the setting has changed, i.e., not in the classroom)
- Study of the place (what happens in and around the place)
- Learning from the place
- Learning for the sake of the place (Granit-Dgani, 2021).

Te Whakaaro Rorohiko or Computational Thinking and its popularised definition involves “the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer – human or machine – can effectively carry it out” (Wing, 2014, para.5). The focus in this paper lies in identifying the most effective pedagogical strategies to utilise with young children when engaging in paper-based coding.

Hangarau refers to the Māori-medium curriculum document that parallels, but is not the same as the English-medium Technology curriculum document. The terms will not be used interchangeably in this paper, and Hangarau will be the key term, as the focus of this paper is on students engaging with storytelling and these robots in a Māori-medium educational context.

In the literature, young children, early childhood, junior primary and early elementary have been used interchangeably to refer to the target age-group, children under the age of 9-years-old. In the New Zealand education sector, early childhood generally refers to babies, toddlers and young children from birth to 5, that are enrolled in early childhood educational settings in Aotearoa New Zealand. This part of the educational sector is guided by a different curriculum framework, Te Whāriki (Ministry of Education, 2017c), and is outside of the scope for this paper. When we are talking about working with young children, we are focusing on students in their first years of primary or elementary schooling, between 5-9 years of age.

60.2 Two national curriculum frameworks

There are two national curriculum frameworks guiding teaching and learning for children between 5 and 18 years-old in Aotearoa: Te Marautanga o Aotearoa (Ministry of Education, 2017a) and The New Zealand Curriculum (Ministry of Education, 2017b). The former supports Māori-medium educators, and is informed by mātauranga Māori (Māori knowledge) and te reo Māori (Māori language). The latter supports English-medium educators. Digital Technologies and Hangarau Matihiko were introduced as additional components of the Technology and the Hangarau curricula respectively in 2017. Computational Thinking or Te Whakaaro Rorohiko was introduced to the curricula as part of this development. Currently, both curriculum documents are undergoing a refresh, which is two years into a six year cycle (see curriculumrefresh.education.govt.nz). The evolving nature of the curriculum was an important consideration for the wider study, and will be discussed further below.

60.3 A study in the use of TUIs with young children

The wider project was called Te Haerenga a Kupe or The Journeys of Kupe. The project had two general goals: To initialise a transdisciplinary research project bringing together engineering, design, and education to explore how young children can use physical components to program robots; and to evaluate and improve an existing robotic programming environment. The improvements included modifying the system so that it was age appropriate for 5-9-year-old children and incorporating New Zealand-based content in the teaching and learning experiences that are planned and delivered with young children.

61 A BRIEF OVERVIEW OF RELATED LITERATURE

The key areas of focus were:

- How have TUIs been used with 5-9 year-old children and were any considerations made regarding the inclusion or exclusion of Graphical User Interfaces (GUIs) or Audio and Video User Interfaces?
- What pedagogical approaches are most effective in the teaching of programming concepts with young children?

61.1 How have TUIs been used with 5-9-year-old children?

Seminal researcher Ishii (2008) defines TUIs as giving “physical forms to digital information” (p.xvi), both representing their digital equivalent and serving to control it. Ishii explains the properties and design requirements of TUIs: the mapping of a tangible representation to underlying digital information; the mechanisms for interaction with these representations (directly manipulated by the user’s hands, or motor- and magnet-driven approaches); and the importance of the perceptual links between both. Prior to Ishii’s introduction of TUIs in 1997, Graphical User Interfaces had evolved from the initial Control User Interface (the latter requiring knowledge of programming and codes to facilitate the operation of and interaction with digital information). GUIs and TUIs have since been extended with Audio, Video and Hybrid interfaces. The trends in the included studies informed the thinking for this study and are expanded on in this section.

Studies were initially categorised by the particular form that the intervention took (i.e., whether the focus lay on a TUI, a GUI, a hybrid interface or another form of interface) and the groups of children who were engaging with this/these interface(s). There were combinations of TUI, GUI (Papadakis, 2022; Cheng et al., 2023), and hybrid (Strawhacker et al., 2013) systems in working with young children with autism (Nonnis & Bryan-Kinns, 2019), with intellectual disability (Beccaluva et al., 2021), with visual impairment (Lang et al., 2023; Pires et al., 2021) and exploring the challenges of inclusive, sustainable robotics when working with low-income communities (Yang et al., 2022). Most of the studies were conducted in a range of classroom contexts, with the exception targeting the preparation of pre-service teachers for teaching computational thinking in school (Angeli & Jaipal-Jamani, 2018). One study focused solely on the robotic system and its tangible and virtual interface to the exclusion of any discussion of classroom context (Bakala et al., 2023).

Studies were then categorised by the application of TUI, GUI, and hybrid systems in different curriculum areas: including mathematics (Drăgănoiu et al., 2022; Pires et al., 2021), literacy (Bezuidenhout, 2021; Fan et al., 2018; Lang et al., 2023), and STEM as integrated disciplines (Çetin & Demircan, 2020; Nikolopoulou, 2022; Tselegkaridis & Sapounidis, 2022), with a small base of studies extending STEM into play-based learning (Aranda et al., 2022) or focusing on more general skills, such as memory (Beccaluva et al., 2021), spatial skills (Baykal et al., 2018), or on a very specific knowledge context – such as farm-to-table food knowledge (Ye et al., 2023). Pugnali et al. (2017) conducted a comparative study into the development of computational thinking with children aged between 4-7-years-old, when using a GUI (Scratch Jr) or when using a TUI (KIBO). Across the activities, and drawing from Brennan and Resnick’s (2012) framework, the children working with KIBO outperformed the Scratch Jr group, arguably due to the more explicit nature of the tangible programming tool. There were only a couple of studies that focused more generally on specific curriculum frameworks or pedagogical approaches to teaching and learning this content, including the Montessori approach (Ahmed Sayed Ali et al., 2021) and the links between Technology-Based Embodied Learning and tangible tools (Zhong et al., 2021).

61.2 2.2 What pedagogical approaches are most effective when teaching computer science?

The diverse range of studies, discussed very briefly in the previous section form the foundation of the argument for the import of pedagogical pluralism (Aranda & Ferguson, 2018). Basically, the design of the learning should be aimed at the specific needs of the children in each of the contexts being researched. We would like to link this concept with the pedagogical principle of designing rich tasks for children to explore computer programming concepts, that would have low floors, high ceilings and wide walls – meaning they would be adaptable and accessible to a wide range of students (Resnick & Silverman, 2005). Alper et al (2012) extend on the metaphor by adding ramps, ladders and frames of interest. Although their focus is on educating students with disability, the principle is one that is incorporated into the daily practise of many teachers, who are looking for ways to provide options in a learning task that challenges, extends and builds on the learning for all students in the class.

Three main models have been identified in teaching computer science: 1) As a separate subject, with a focus on programming; 2) As a vehicle to develop digital literacy; and 3) A combination of the first two models. Each of the three conceptualisations result in different curriculum, resourcing and teaching requirements (Fessakis et al., 2018). Bers (2019) advocates for teachers to see the parallels between teaching computer science to young children and teaching another literacy. Zeng et al. (2023) conduct a systematic literature review as they refine an earlier framework developed by Brennan and Resnick (2012) so that it is age-appropriate for young children under 8-years-old.

Sapounidis and Demetriadis (2017) argue that the establishment of knowledge through play is pedagogically important, along with the cycle where decision making reinforces students' reasoning. Their focus on TUIs as lowering the age threshold to teach programming concepts. What are the unique opportunities that tangible programming offers to the field of educational robotics? Skills developed include critical thinking skills and problem solving. They recommend further research systematically exploring the "cognitive and social advantages of TUIs compared to traditional GUI solutions" (p.212).

61.3 2.3. Key Lessons Learnt

Complexity arises from the number of extraneous factors that directly impact the results of these studies (which includes teaching style, expectations, use of resources, diversity in learners, the curriculum used in the class). Generally, researchers concluded that the studies needed to be as specific and narrowly focused as possible, to be able to generate robust findings. However, the techniques employed in exploring developmentally appropriate delivery transcended the mode that researchers had chosen, with pseudo-language seen as important in the development of TUI, GUI and hybrid content.

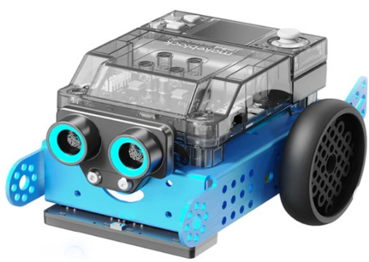
Whether the study was a small pilot study or a big data project over multiple years, involving hundreds of children, researchers focused on the pedagogical design of the delivery of concepts and how to refine the design of concepts when challenges in the communication of those ideas were identified. Generally, children were part of the research circle, and their teachers or families were also involved, dependent on the specific research context. The involvement of teachers and families was generally to facilitate a sustainable approach to the intervention (if the intent was that the intervention would be ongoing), but also to support and strengthen communication of thinking during the research process.

This study identifies the teaching of computer science as aligning with the third model discussed in the previous section; that is, programming as a discipline; and computer science as a vehicle to develop digital literacy. The authors agree with Bers (2019), in that the teaching of computer science to young children should be approached as the teaching of a new literacy. These considerations influenced the method for this study, discussed below.

62 3. METHOD

62.1 System Design

Figure 33
The mBot neo



The key criteria that our choice of system was based on were:

- The robot and the components should be cheap and available internationally;
- Materials to use for the TUIs should be widely available;
- That a geographic map (see Figure 3) would provide the context for the students' learning experiences;
- That people without technical backgrounds would be able to easily modify the end system.

Based on the above criteria and our literature review we chose the mBot neo for the base of our system (see Figure 1). We complemented this with Raspberry Pi, a smart camera, and CyberPi (Naude et al., 2023). There were two paper-based components: the maps (see Figure 3), and the command cards (see Figure 2), which included the following commands:

(i) Forward: move the robot in the direction of the camera.
(ii) Stop: turn the robot's motors off.

(iii) Turn left: turn the robot to the left, relative to the camera at the front of the robot.
(iv) Turn right: turn the robot to the right.
(v) Speech: record five seconds of speech from the user.
(vi) Location: replay the recorded speech from the user.

Figure 34
The Command Cards Children Used to Programme the Robots

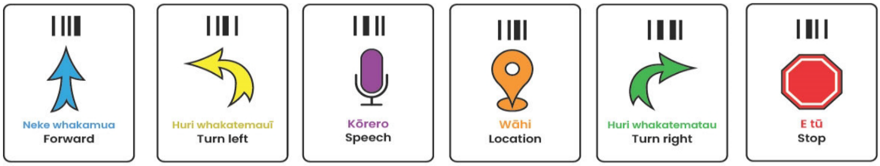
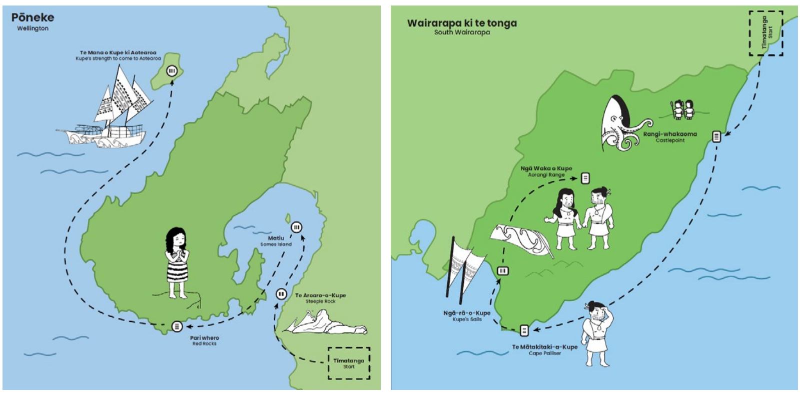


Figure 35
Maps of the Wellington Region, and the Journeys of Kupe the Māori Explorer



62.2 Data gathering and participants

Over 2022, we organised 12 visits to eight different schools. During these visits, over 300 children used the system. Most visits involved a single class, but some visits involved either multiple classes or sub-groups within a class. The smallest number of children in a session was nine children, and the largest was over 60. The median session size was 14 children.

Whakaaro hātepe and hanga hātepe (algorithmic thinking and writing algorithms) were the tupuranga whakairo rorohiko or computational thinking progressions that were the focus of the learning experiences. The choice of algorithms aligned with Brennan and Resnick's (2012) framework and was supported by the inclusion of patuiro (debugging) as an integral part of the learning experience.

Data were gathered using multiple avenues. Each of the mBots recorded a log of their programmed actions during each session. We recorded field notes and observations. Children shared their feedback both during the sessions (as a particular problem or thought arose) and at the end of the session (usually orally, although one class wrote a big book that they shared with us to communicate their learning with the mBot neos. Teachers shared their feedback during the session, or after the session (either orally or via email)).

62.3 Pedagogical decisions: How each session ran

Each session, we would sit the students in a circle, introduce the robots and explain how they worked. We would demonstrate how the command cards worked. We then introduced the location cards and demonstrated how the children needed to navigate between the different numbers. Because the students were young children, we ensured that, as part of the introduction of the robots, there was an explanation of tikanga (What practices were going to support the children in turn-taking? What practices would support the children in looking after the robots?) The children were then split into groups (either by the teachers or the researchers, depending on the teacher's preference).

A child was nominated as the group leader. They took the first turn, then designated the next person in the group who would take their turn. Each child received a full set of command cards; each group was given a robot, a set of number cards, and once the initial activity was complete, we moved the children onto the maps of the Wellington region (see Figure 3) so they could engage with the narratives that, at this stage, had been prepared on cards. During this time, the researchers would circulate and provide support as needed. The duration of the session variedin relation to the children's interest levels.

All sessions lasted between 20-40 minutes. Typically, older children would lose interest in the robots sooner. They were able to figure out how the robots and commands worked and quickly adapt to changes. In contrast, younger children generally took longer to understand how the robots worked. They needed more help when they encountered problems.

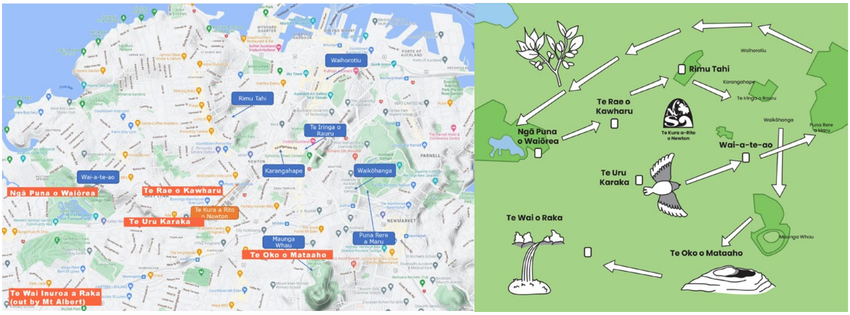
63 FINDINGS: AN UNEXPECTED RESEARCH OUTPUT

This paper focuses on a school that was visited three times and the way in which the principles of place-based education were applied in response to feedback from the children and the teachers, so that the children were able to engage with narratives of the area in which they go to school. In each of the visits, we invited feedback: How could the system be improved? What had worked well? What was challenging? When this school was sharing their feedback, the children decided that it would be more significant to them and their learning, if the narratives they focused on belonged to central Auckland – the area their school was in, that they chose to connect to as students and teachers.

We sat with the group and they shared a mōteatea (traditional chant) composed by Hareruia Aperahama for the group. This mōteatea is called Rupe Rere Nui, Rupe being a New Zealand pigeon, referred to in personified form as Rupe. Rupe's great flight was marked out on a map and we have begun the process of developing a map that can focus on the narratives of this central Auckland group of students (see Figure 4).

Figure 36

The Initial Markings on the Map made with Students (at left) and the Current Iteration of the Map Being Developed (at right).



64 INITIAL CONCLUSIONS AND FURTHER RESEARCH

It is interesting that, of the eight schools we visited (all within the Auckland region), there was only one class in one school that asked about their place: Could we make our own map of the places to which we connect? The group decided that they wanted something they would be able to engage with in the long-term, related to the place where their school connected. We believe place-based education is vital and were happy to respond to the students' requests. We wonder if this question was raised by this group, because of the centrality of place-based education in Māori-medium educational contexts. With the current curriculum refresh, there is the potential for this to grow across the educational sector. We highly recommend further research and the development of modules, so that the schools we work with, are able to easily adapt the materials and develop local maps where teachers and young children can work together and engage in storytelling about the places they choose to connect to on a daily basis.

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Situating Spatial Ability Development in the Craft and Technology Curricula of Swedish Compulsory Education

Ting-Jun Lin, KTH Royal Institute of Technology, tingjun@kth.se
Jeffrey Buckley, Technological University of the Shannon, jbuckley@ait.ie
Lena Gumaelius, KTH Royal Institute of Technology, lenagu@kth.se
Ernest Ampadu, KTH Royal Institute of Technology, ernesta@kth.se

ABSTRACT

Spatial ability has been shown to have a causal relationship with students' success in science, technology, engineering, and mathematics (STEM) subjects. While an abundance of research has investigated how spatial ability development is and could be integrated to science, engineering, and mathematics curricula, little attempt has been made to date to situate where spatial ability manifests in technology curricula. This paper uses document analysis to examine the locations of spatial ability related learning outcomes within the craft and technology curricula in Swedish compulsory education. A qualitative inductive approach is employed to analyse the policy document from the Swedish National Agency for Education. We argue that spatial ability development manifests in the Swedish craft and technology subject curricula along two dimensions. First, the curricula are underpinned by visual components, which are graphical, pictorial, and manufactured components. Second, along with the visual components, the curricula are delivered with the aim of constructing students' conceptual and procedural knowledge. Whilst the technology curriculum dominantly cultivates students' conceptual and procedural knowledge by interacting with the graphical and manufactured components such as sketches and objects, the craft curriculum is taught in a more diverse way where students are not only required to deal with graphical and manufactured components but also to involve in various pictorial components that convey cultural and historical meanings by craft products.

Keywords: Technology education, spatial ability, document analysis, Swedish compulsory education

1. INTRODUCTION

Spatial ability refers to the ability to mentally create, store, understand, reason, retrieve, and transform visual images (Kyllonen et al., 1984; Lane & Sorby, 2022; Lohman, 1996). We harness spatial ability in our daily life. From two to three dimensions, we engage with lines and points that form various geometric flat shapes such squares and circles, and we interact with solid objects such as cubes and buildings (Lane & Sorby, 2022).

Spatial ability has garnered substantial attention in science, technology, engineering, and mathematics (STEM) education globally (Buckley et al., 2018; Stieff & Uttal, 2015). While an abundance of research has investigated how spatial ability development could be integrated to science, engineering, and mathematics curricula, little attempt has been made to investigate where spatial ability manifests in specific curricula of technology education.

Many European countries have included technology education into their national compulsory curricula. For example, Finnish technology education is compulsory for pupils aged from 7 to 15, aiming to boost their self-esteem through cultivating their understanding, creativity, and hands-on skills of manufacturing and crafting (FNBE, 2016). In Slovenia, compulsory technology education is delivered through the design and technology (D&T) curricula for pupils aged from 9 to 13, aiming to develop pupils' problem solving and creative thinking skills (OECD, 2022). D&T is also part of the national curriculum in the UK for pupils aged 4 to 11 (Brown, 2022). In addition, Estonia, Iceland, Ireland, and Sweden also offer technology education for pupils in primary and secondary schools (Autio, et al., 2019; Lane & Sorby, 2022). This paper is conducted in the context of Swedish technology education.

Technology education in Sweden is mandatory for pupils of 7 to 16 years old. Currently, Swedish technology education has been divided into two separate curricula—craft and technology. While teaching craft aims to develop pupils' knowledge of various artefacts and skills in merging thinking, sensory, and hands-on experience together, teaching technology prepares pupils for the fast-changing technology world through developing their technical awareness and expertise. This paper is to investigate the locations of spatial ability related learning outcomes within the craft and technology curricula in Swedish compulsory education. The results of this paper will not only contribute to the qualification of where spatial ability is represented, but in how they interact with curricular knowledge, which can provide educational researchers and practitioners with increased insight into designing and implementation of effective pedagogical strategies.

66 LITERATURE REVIEW

66.1 Spatial ability and STEM performance

Spatial ability and its malleability have been empirically shown to correlate with the success of STEM learning (e.g., Posamentier et al., 2021; Stieff & Uttal, 2015), resulting in substantial spatial trainings in the STEM-related fields (e.g., Lane & Sorby, 2022; Lowrie, et al., 2017). Researchers have suggested some in-depth reasons why the correlations take place between spatial ability training and STEM performance.

First, the correlations might take place when the practice of spatial ability shares domain-general and domain-specific cognitive processes with the problem-solving process of a subject. Take mathematic as an example, the shared cognitive processes between the use of spatial ability and mathematical problem solving might be the processes that require mental rotation ability (i.e., domain-general) and that require spatial transformation for geometry and measurement problem solving (i.e., domain-specific) (Hawes, et al., 2022). Hence, the natural connection between spatial ability and mathematical performance could be bound.

Second, spatial strategies are applied by learners when solving STEM problems. For example, in chemistry learning, Stieff et al. (2020) found that novice chemistry students automatically recruit spatial ability strategically to process the embedded information in those chemistry representations, regardless of their insufficient domain knowledge of chemistry. Similar examples could also be found in technology education. Technology subjects often involve hands-on activities such as sketching and modelling (Lin, 2016). Learners would naturally hone their spatial orientation as well as fine motor skills in these hands-on activities, which respectively refer to the ability to measure angles and distances and the skills to transform visual information into fine motor activities (Posamentier et al., 2021).

Therefore, spatial ability development is not only naturally situated, but also potentially to improve pupils' technology subjects learning.

66.2 Spatial ability in technology education curricula

Generally, technology education has inherited the vocational nature, and its required skill sets are used and developed in many of today's technology-related fields (Buckley et al., 2018). The required skill sets often involve spatially-focused skills such as sketching, modelling, drawing and so on (Lin, 2016). Researchers have found that spatial ability is positively related to one's success in the technology-related fields (e.g., Julià & Antolí, 2016). Indeed, compared to verbal descriptions, using graphical representations such as symbols not only makes the ways of conveying messages among technologists more effective, but also allows technologists to keep the records of the design process for reference (Ben & Berry, 2012).

Previous studies have shown that a high portion of spatial tasks are embedded in some national curricula of STEM-related subjects (Lowrie, et al., 2017). However, most of the previous investigations are conducted in the subjects of mathematics (e.g., Lowrie, et al., 2017; Ramful, et al., 2017) and science (e.g., Sugai & Suzuki, 2011). For example, according to Lowrie et al. (2017), most national mathematics evaluation programmes tend to shift away from word-based tasks to quantitative as well as graphics content for learners to decode. This paper initiates the first attempt to examine how spatial ability is situated in the technology education curricula in the context of Swedish compulsory education. Particularly, two technology-related subjects are investigated—craft and technology.

67 METHODOLOGY

67.1 The Swedish compulsory curriculum

The curriculum document *Curriculum for the Compulsory School, Preschool Class and School-age Educare* by the Swedish National Agency for Education was examined (Skolverket, 2018). The document is structured by five sections—*the fundamental values and tasks of the school, overall goals and guidelines, preschool class, school-age educare,* and *syllabuses*. This paper is mainly to address how spatial ability develops within the curricula of craft and technology, targeting pupils who age around 7-16 years old (i.e., Years 1-9). Hence, only the *syllabi*, more specifically, *syllabuses* for craft and technology, will be examined.

The *syllabuses* include *subject aim, core content,* and *knowledge requirements*, which show the intended learning outcomes, the required subject knowledge and skills, and assessment criteria respectively. Pupils' achievements are evaluated by the end of Years 6 and 9. Based on the *knowledge requirements*, pupils' performance is graded by the ranking letters from A (highest performance) to F (fail).

67.2 Coding

A qualitative methodology was adopted to analyse the document by using the analysis software NVivo. First, the authors read the craft and technology syllabi and identified the content that relates to spatial ability development, referred to as "spatial-related content" in this paper. The identification of the spatial-related content was mostly based on the spatial literature and supplemented by the authors' expertise. The authors of this paper have substantial research experience upon the topics of spatial ability development as well as curriculum development.

Second, an in-vivo and descriptive coding method was conducted on the syllabi. Specifically, a code was assigned to a spatial-related content by either extracting a word from the content (i.e., in-vivo coding) or creating a new term (i.e., descriptive coding) (Charmaz, 2006). Table 1 shows the examples of the in-vivo and descriptive coding process. A codes list was generated after the coding process.

Table 1. Examples of in-vivo and descriptive coding

Content	Subject	Codes	Coding method
Developed forms of **handicraft** techniques, such as moulding, weaving and cutting and turning metal.	Craft	Handicraft	In-vivo
What computers are used for and some of the basic component parts of a computer for entering, retrieving and storing information, such as keyboards, monitors and hard disks.	Technology	Object structure	Descriptive

Third, the authors read the codes and reviewed the coding process together. Disagreements regarding the codes were addressed through constant discussion. 27 codes were generated, with 15 codes from the craft syllabus and 12 from the technology.

Fourth, the 27 codes were then re-coded by an axial coding technique. All authors got familiar with the codes and looked for patterns among them. Two main dimensions with 5 sub-dimensions were identified. The first main dimension represents visual components that pupils engage in craft and technology learning. These visual components include three sub-categories, which are *graphical*, *pictorial*, and *manufactured* components. Codes are mapped to these sub-categories in the following ways:

- Graphical components: codes that expose schematic features such as “symbol” and “model”. They are in a two-dimensional form with the essential attributes that show the details of the structure, framework, and construction of an entity.
- Pictorial components: codes that show contextual features such as “picture” and “materials”. They are in a two-dimensional form with not only schematic features but also more aesthetic details such as colours and texture.
- Manufactured components: codes that refer to a three-dimensional entity which combines both graphic and pictorial components such as “handicraft” and “artefacts”.

After all codes were mapped to the visual components, they were categorised into the sub-dimensions of the second main dimension. The second main dimension represents the type of knowledge that pupils acquire, which indicates how pupils’ knowledge is learned. Two sub-dimensions—conceptual and procedural knowledge—are contained in the second main dimension.

- Conceptual knowledge: knowledge that pupils acquire about the concepts, principles, as well as cultural and historical facts of an entity.
- Procedural knowledge: knowledge that pupils are applying while carrying out hands-on activities to reach a solution of a problem.

The categorization of codes into conceptual and procedural knowledge is based on the context of the spatial-related content. For example, the context of the spatial-related content “*two- and three-dimensional sketches, models, patterns and task descriptions, both with and without digital tools*" (Skolverket, 2018, p. 256) indicates that pupils are required to understand how sketches, model, patterns and task descriptions could be interpreted and related to mathematical calculations, which falls into the sub-dimension of conceptual knowledge. Also, the context of the spatial-related content “*pupils' own constructions applying principles for solid and stable structures, mechanisms and electrical connections, in the form of physical and digital models*" (Skolverket, 2018, p.298) suggests that pupils need to conduct a hands-on construction of model by applying theoretical knowledge, which falls into the sub-dimension of procedural knowledge.

Finally, the spatial-related content of the 27 codes were re-coded by a new pair of codes. To be specific, the new pair of codes consist of one visual component and one knowledge type. Table 2 shows an example of how the spatial-related content in Table 1 was re-coded by a new pair of codes. The spatial-related content could be re-coded by more than one pair of codes if the content falls in more than one sub-dimension.

Table 2. Examples of axial coding

Content	Subject	Codes	Coding method
Developed forms of handicraft techniques, such as moulding, weaving and cutting and turning metal.	Craft	Manufactured, Procedural	Axial

What computers are used for and some of the basic component parts of a computer for entering, retrieving and storing information, such as keyboards, monitors and hard disks.	Technology	Graphic, Conceptual	Axial

68 RESULTS

The spatial-related content occupies 58.1% of the craft syllabus and 34.4% of the technology syllabus. The percentage is calculated by dividing the number of coded word characters by the total number of word characters of the syllabus (NVivo). While both the craft and technology curriculum expose pupils to spatial ability development, the percentages of the spatial-related content suggest that pupils might have higher chances to develop spatial ability in craft curriculum than technology.

68.1 Spatial ability development in the craft curriculum

Table 3 shows the frequency and percentages of the codes in the spatial-related content of the craft syllabus. The numbers indicate that pupils are required to acquire more conceptual knowledge than procedural knowledge in the craft curriculum. Pupils need to acquire factual understandings of a craft process. These factual understandings include conceptual, cultural, and historical knowledge of the graphic (e.g., symbols and structures), pictorial (e.g., inspirational materials), and manufactured (e.g., handicraft and artefacts) components. Pupils need this knowledge so that they can interpret and assess the aesthetic and cultural meanings behind the product and apply the knowledge to create their own craft product. To deliver procedural knowledge, pupils are required to make simple two- and three-dimensional sketches for craft design (graphic, procedural), document their work process with pictures (pictorial, procedural), to explore design opportunities by the given materials (pictorial, procedural), and to create their own craft product by using some tools and instruments (manufactured, procedural).

Table 3. Codes frequency and percentages of the craft syllabus

Codes	Codes frequency	Occupation of codes among the spatial-related (percentage)
Graphic, conceptual	9	14.1%
Graphic, procedural	2	3.1%
Pictorial, conceptual	11	17.2%
Pictorial, procedural	14	21.9%
Manufactured, conceptual	17	26.6%
Manufactured, procedural	11	17.2%
In total	64	100%

68.2 Spatial ability development in the technology curriculum

Table 4 shows the frequency and percentages of the codes in the spatial-related content of the technology syllabus. The spatial-related content predominantly clusters at graphic and manufactured components along with both conceptual and procedural knowledge. Pupils should have the knowledge of the structure of a technical or mechanical system of some everyday objects such as computers, data networks, electricity, or a bridge. Specifically, pupils need to understand the part-and-whole relationship between the components of a system and a system as a whole (graphic, conceptual). Also, they need to know how an individual technical or mechanical system works to produce expected effect for daily life such as how the technology works in order to produce sound, light or movement (manufactured, conceptual). Similar to craft curriculum, spatial-related content in technology curriculum also requires pupils to document their work process. However, while craft curriculum requires pupils to document by using pictures, technology curriculum needs students to use simple sketches, symbols, and drawing to document their process (graphic, procedural). Also, pupils are required to carry out some technology solutions through controlling an object by programming and applying mechanisms in their own construction of technology (manufactured, procedural). Compared to craft curriculum, pupils seem to engage less with the pictorial components in their technology learning. Only two pictorial components in the technology curriculum were identified along with conceptual and procedural knowledge. First, picture is used in documentation of work process by pupils at the Year 1-3 (pictorial, procedural). Second, pupils should have the knowledge of the properties of some everyday materials such as wood and concrete.

Table 4. Codes frequency and percentages of the technology syllabus

Codes	Codes frequency	Occupation of codes among the spatial-related content (percentage)
Graphic, conceptual	14	29,17%
Graphic, procedural	10	20,83%
Pictorial, conceptual	4	8,33%
Pictorial, procedural	3	6,25%
Manufactured, conceptual	7	14,58%
Manufactured, procedural	10	20,83%
In total	48	100,00%

69 DISCUSSION AND CONCLUSION

This paper examined the locations of spatial-related content within the craft and technology curricula in Swedish compulsory education. The results show that spatial ability development is embedded in both curricula to a different extent. Specifically, in craft curriculum, spatial ability is developed through requiring pupils to work on all visual components (i.e., graphic, pictorial, and manufactured) while inclining to construct their conceptual knowledge rather than procedural knowledge. Technology curriculum, despite its smaller portion of spatial-related content than craft curriculum, is also embedded with spatial ability development mainly by exposing pupils to graphic and manufactured components, and it requires similar portions of conceptual and procedural knowledge of pupils.

The results could be explained and supported by previous spatial literature. The manifestation of spatial ability development in Swedish national craft and technology curricula is supported by the conceptualization of spatial ability by researchers. Two of the most cited conceptualizations are from Lohman (1996) and Schneider and McGrew (2012). According to Lohman (1996), spatial ability is the ability to "*generate, retain, retrieve, and transform well-structured visual images*" (p. 98). Contemporarily, Schneider and McGrew (2012) considered spatial ability as "*the ability to make use of simulated mental imagery to solve problems—perceiving, discriminating, manipulating, and recalling nonlinguistic images in the 'mind's eye'*" (p.125). Both conceptualizations indicate a mental process of manipulation and transformation of visual images, which might be represented by pupils' conceptual and procedural knowledge in this paper.

For example, in craft curriculum, pupils are asked to interpret a craft artefact by reasoning its symbols and form (Skolverket, 2018). Pupils need to manipulate the symbols and form in mind, starting from perceiving the symbols and form, then retrieving the visual knowledge that they store in mind previously, and finally reasoning the symbols and form with the previously-stored knowledge. In addition, one of the hands-on tasks in technology curriculum is to transform raw materials into a finished product by pupils (Skolverket, 2018). Other than manipulating the objects (i.e., raw materials) in mind such as perceiving the structure and sizes of the objects, pupils also need to mentally transform the nature of the objects and visualise the finished product, which demonstrate one of the core capabilities of spatial ability—spatial visualisation (Kyllonen et al., 1984).

The results fill in the literature void of compulsory curriculum in conjunction with spatial ability development. Particularly, the results uncover how spatial ability development integrates into the technology education curricula and how it interacts with the technology-related subject knowledge (i.e., craft and technology). In addition, this paper examines the compulsory curricula at a national level, which guides the rationale, aims and objectives, as well as content of the curricula at micro levels (Akker, 2003).

Educational researchers and practitioners who work at school and classroom levels could gain insight from the results of this paper. As teachers possess the freedom to interpret the curriculum and design their pedagogies in the classroom (Bernstein, 2018), with knowing how spatial ability development integrates into the curricula, they could design and implement pedagogical strategies that are effective to develop pupils' spatial ability. For example, teachers could be more aware of the visual components that show up in the craft and technology curricula, engaging pupils to perceive and chunk visual components into more visual information (Stieff, et al., 2020), such that pupils' visuospatial capacity could be increased and further lead to a better performance in craft and technology curricula.

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Primary School Students' Perception of Technology

Johan Lind, Malmö University, johan.lind@mau.se

ABSTRACT

Research on students' perceptions and understanding of technology has shown that students have a narrow view of technology: for example, technology is often manifested in students' descriptions as artefacts or objects. This paper aims at investigating how students develop understanding of how technology is manifested during classroom activities in technology. The study was conducted at a compulsory primary school with eight-year-old students. The data (video and audio recordings) were collected in small-group interactions and whole-class discussions. In the interactions, the students utilised self-taken photographs to visualise their understanding and perception of technology. The analysing process is grounded in Mitcham's (1994) manifestations of technology: object, activity, volition, and knowledge. Based on the students' prior knowledge, they perceived technology as contemporary electrical artefacts. The findings indicate that students achieve a more nuanced perception and understanding of technology as objects during classroom activities in technology.

Keywords: interactions; manifestations of technology; primary school; technology education; technological artefacts

1. INTRODUCTION

In technology education, a common approach is to introduce students to technological artefacts as they are easy to comprehend and visualise. In addition to that, de Vries (2016) states that students commonly view technology as artefacts. However, this approach could lead to students having a limited understanding of technology. The studies reviewed in this paper, using Mitcham's typology, agree that students of various ages have a limited perception of technology with most viewing technology primarily as artefacts or objects and some also describing it as activities. Nonetheless, it is essential to support students to enhance their understanding and knowledge of technology. This is a crucial aspect of technological literacy, as students need to comprehend central technological concepts as well as the relationship between technology, society, individuals and the environment (ITEA, 2006). Additionally, if students realise the impact of technology on their lives, it can provide them with agency and responsibility. While previous studies highlight the importance of improving students' perception of technology, there is a lack of empirical research examining how students encounter a wider perception of the manifestations of technology during technology education activities. Therefore, the present study seeks to address this research gap.

Su and Ding (2022) concluded that students generally define technology by its contemporary characteristics, such as artefacts requiring electricity to function. Similarly, Ankiewicz (2016) noted that students' concepts of technology are often insufficient and primarily focus on contemporary artefacts. Therefore, primary school technology education plays an essential role in shaping and developing students' understanding of technology (Su & Ding, 2022). Additionally, this understanding is essential for developing technological literacy, which involves, amongst other things, understanding of what technology is, how it evolves, and how it is created (ITEEA, 2020).

This paper aims at exploring how primary school students, in interactions with fellow students and teachers, perceive and communicate understanding of technology manifestations. This understanding involves Mitcham's (1994) aspects of technology that may become visible in student interactions. This study considers the interactions between students in small groups (2–4 students in each group) and between teacher and student in whole-classroom discussions (e.g., Mercer & Littleton, 2007). Thereby, it is possible to identify and analyse in what ways students communicate an understanding of how technology can be manifested by using verbal language to formulate ideas and construct an understanding of technology together with fellow students and their teacher (e.g., Howe et al., 2019; Hennessy et al., 2020; Mercer, 2000; Vygotsky, 1978). The research question addressed in this study is:

> In what ways do students perceive how technology is manifested?

71 LITERATURE REVIEW

Technology may include a large number of basic concepts (de Vries, 2016b), which can be divided into five categories: designing (elements in designing, such as invention and practical reasoning), system (concept of systems and subsystems, such as artefacts, structure and function), modelling (visualisation etc.), resources (such as material, humans and information) and values (sustainability, risk/failure etc.). Various concepts have been employed in technology education to clarify the functioning of artefacts. Thereby, those concepts are considered essential to students' development of a comprehension of how society and technology are interrelated and affect each other (de Vries, 2016b; Koski, 2014) and therefore taught in schools. According to de Vries (2016) technology can be described as experience-based, macrotechnologies and microtechnologies. Experience-based technologies are technologies that have been developed through human experimentation throughout history. Macrotechnologies are based on fundamental theories such as mechanics. Finally, microtechnologies are essential parts in microscopic technology.

Technological artefacts are humans' first encounters with technology and any object that is intentionally designed, made, and utilised by humans to achieve a certain goal (de Vries, 2016). Thus, technological artefacts only exist in relation to humans' intentionality, meaning that the artefacts are manufactured rather than just existing as physical objects. In that context, Kroes and Meijers (2006) state that technological artefacts have a dual nature: described from physical and functional aspects, which combines different ways of perceiving the world. The dual nature of technological artefacts indicates that technological artefacts are physical structures designed to fulfil functions determined by humans' intensions (Kroes & Meijers, 2006).

Mitcham (1994) categorised technology into four modes of manifestation: objects, knowledge, activity, and volition. According to Mitcham (1994), technology as object refers to the most immediate and visible mode of technology, encompassing human-made material artefacts, such as clothes, utensils, tools, and machines. Technology as knowledge involves mental knowledge, which is required for making and using technological artefacts. Technology as activity relates to the combination of knowledge and volition in constructing artefacts and can be seen in various human actions such as crafting, inventing, designing, manufacturing, working, operating, and maintaining. Lastly, technology as volition is associated with different kinds of will, motives, and intentions (Mitcham, 1994).

71.1 Previous research on students' perception of technology

Blom and Abrie (2021) found that students (South African ninth- and tenth-graders) have limited perceptions of technology. By utilising Mitcham's typology of technology in the analysis they concluded that the students most often associated technology with objects and/or activities, thus disregarding technology as knowledge and volition. The findings also imply that a majority of the students related technology to new electronic objects and the technological activity to designing, making and utilising technology (Blom & Abrie, 2021).

In the same way, Su and Ding (2022) conducted a study on Chinese primary school students, 9–12 years of age, and investigated their conception of technology, how technologies affect human life and the interrelations between science and technology. In the study, the researchers used images to encourage students to describe technology and also interviewed the students. The findings indicate that students describe technology from various aspects, such as the dimensions of its features, production, function, operation, and use. Su and Ding (2022) stated conclusively that primary school students, in the study, perceive technology insufficiently and have difficulty understanding the relationship between science and technology. Although some studies found that students perceive technology in a limited sense, Su and Ding (2022) stated that, regarding Mitcham's typology, all four aspects of technology were represented in their findings.

Svenningsson's (2020) study revealed that, like previous research, Swedish students describe a limited view of technology. By utilising a deductive method in the analysis of the 164 students (aged 12–15) descriptions of technology, Svenningsson found that the students most commonly describe technology as objects, with modern electrical objects being the most frequent examples mentioned. Although Svenningsson investigated other ways in which students could potentially describe technology, such as volition and knowledge aspects of technology, students' perceptions of technology were largely limited to technology as objects and activities. However, the results indicate that students have the potential to describe technology more broadly by using all four manifestations of technology outlined in Mitcham's typology.

72 METHODOLOGY

72.1 Setting and participants

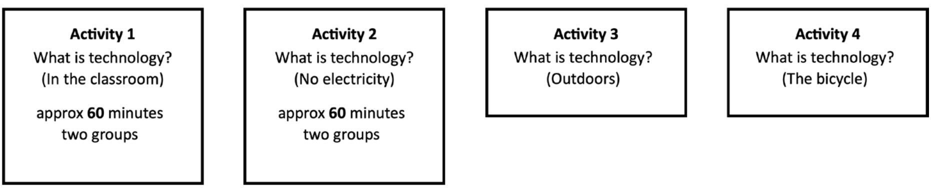
To approach the research question, communicative situations were arranged, in which the students were encouraged to discuss, explain, and talk about technology. The study adopted a qualitative research method grounded in a sociocultural perspective on learning, which implies exploring students' learning through spoken interactions, communication, and reasoning together (Hennessy et al., 2020; Jakobsson & Davidsson, 2012). The tablet camera constitutes decisive support as it helps the students focus attention on a specific object and the self-taken pictures purposively provide appropriate support for the students to evolve interactions in the follow-up dialogues between students (e.g., Hennessy et al., 2020; Lind et al., 2019).

In the analytic process, Mitcham's (1994) typology of technology was the starting point. This was perceived as suitable when analysing students' descriptions of technology as it includes concepts found in students' descriptions of technology, in previous research (Blom & Abrie, 2021; Su & Ding, 2022; Svenningsson, 2020).

72.2 Collecting data

For data collection, audio recorders (10 pcs) and video recorders (2 pcs) were utilised: and placed in the student groups' workplaces. In this way, it was conceivable to get close to the students' interactions by being able to see and listen to the material multiple times (Cohen et al., 2011). The data were collected in two classes during two teaching sequences and comprised two occasions of 60 minutes (activity 1 and activity 2). The regular teachers were responsible for the teaching and learning activities.

Figure 37
Classroom activities



The overall purpose of the teaching sequences was to enable students to perceive technology in their nearby surroundings. The data collection occasions constitute pre-decided learning situations from the whole teaching sequence (Figure 1). This means that the students had approximately seven lessons of which two are in focus for this paper. Between the data collection sessions, the teacher used the students' pre-understanding of technology, identified in a previous activity, to create situations where the students were given the opportunity to develop an understanding of the world around them and how it is structured. A significant part was understanding how and why technological artefacts are developed and how they work. In this context, the teacher and students use subject-specific terms, such as artefacts, components, and technological systems, to broaden students' conceptual understanding of technology. An additional aspect was to make students perceive that technological solutions, like artefacts, are surrounding them. These situations involved engaging the students in conversations around their photographs and the teacher's questions, which involved different aspects of technology and thus enabled a broadening of understanding of the concept of technology. The questions were identified as very important in guiding the students' conversations and thereby leading them towards a broadened understanding of technology.

The two occasions were selected because the classroom activities provided possibilities for taking pictures, time for discussions and working in groups. In total, there were approximately 8,5 hours of collected data.

72.3 Ethical considerations

As the students in the present study are young (aged 8-9), it is ethically required to obtain informed consent from the guardians, even though the data collection is taking place in an ordinary teaching situation (Shammo and Resnick, 2015; Utbildningsdepartementet [Department of Education], 2021). Accordingly, I applied for and received ethical approval from the Scientific Council (Codex, 2022).

72.4 Analytic process

The analytic process comprised three separate but interrelated phases. The first phase involved identifying all situations in which students expressed ways in which technology can be manifested. This was done by using the critical incident technique (Angelides, 2001). A critical incident could be described as the interpretation of the significance of a situation (Angelides, 2001), which characterises and reveals a particular feature of a student's behaviour, such as a question, an action, or an expression of understanding (Cohen et al., 2011).

The second phase took a deductive approach using Mitcham's typology of technology and the four modes of manifestation: Objects, Knowledge, Activity, and Volition. The choice of framework for interpretation is grounded in the fact that this is a well-explored model (e.g., Ankiewicz, 2019; Blom & Abrie, 2021; Su & Ding, 2022; Svenningsson, 2020) and that it contributed to increasing our understanding of how eight-year-olds consider and understand how technology is manifested. Furthermore, the framework was found to be fruitful as it could be used for this data material to explore how the students discuss technology during the activities.

The third phase of the analysis included a discussion, regarding technological artefacts: the manifestation of technology as objects. The results of the analysis are described both through excerpts from student interactions related to various manifestations of technology and by relating students' perceptions of technological artefacts to previous research to develop a broader understanding of primary students' perception of technology.

73 FINDINGS

The chosen excerpts are of interest because they demonstrate significant examples of how students perceive technology throughout the collected data material. The excerpts are extracts from longer interactions.

73.1 Activity 1

In the first activity, the students worked unconditionally with the question "What is technology?" and used a tablet camera for documentation. The students photographed and focused their attention on technology in the classroom. In the subsequent interactions, they mainly focus on technology, which could be described as contemporary objects.

Table 18
Excerpt 1

Teacher	Which images did you choose for technology?
Ava	iPad, iPad cabinet or charger, laptop, headphones, and watch
Teacher	Why is it Technology?
Ava	We believe because we think because they conduct current

In this excerpt, Ava interacts with the teacher and argues that iPad, iPad cabinet or charger, laptop, headphones, and watch are technology, which are considered objects or artefacts. Further, she states that it is technology because it conducts current. Here, one could emphasise that the student might have misunderstood the concept of conducting current, it would be more appropriate to say function with current. However, as this is a learning situation, it is most likely that the teacher utilises their utterances as a way to deal with expanding students' understanding of the concept of technology as the work proceeds. After the first activity, it was obvious that the students' perception of technology was related to contemporary artefacts functioning with electricity.

73.2 Activity 2

In the second activity, the students continued working with the question "What is technology?": now requested to exclude electric-powered artefacts. The camera was used in a similar way as in the first activity. The students looked for artefacts that function without electricity and identified, photographed and utilised the pictures in the group interactions. The class discussion started by referring to the previous activity to challenge the students' understanding that artefacts can function with or without electricity.

Table 19
Excerpt 2

Milad	Things that humans have made
Teacher	Why have humans made these things? Discuss in your group
Cy	To have a better life, you can use them for different things
John	I know
Cy	Kind of like the iPad
John	You can use it to write and stuff like that
Cy	Pencil too, you can write

The statement from Milad allows the teacher to post a question to the class and ask them to proceed with discussions in their groups. In the group discussion following that, Cy and John elaborate on Why have humans made these things?. Cy's To have a better life, you can use them for different things could indicate that he believes artefacts (technology as objects) are intentionally created for humans' lives to be better. However, he continues his argumentation on the question by stating Kind of like the iPad and invites John to display his perception of technology You can use it to write and stuff like that. Finally, Cy adds the pencil as he likely compares the two artefacts, iPad and pen, and their joint opportunity for writing activities. By comparing the artefacts' features, the students, without thinking about it, make a reflection on technological development and how diverse writing tools can be used. It is possible to interpret the students' presented technology as objects as both microtechnology (the iPad) and experience-based technology (the pencil). According to Kroes and Meijers (2006), elaboration on the artefact's feature (to write) could be looking at one of the aspects of the dual nature of artefacts: artefacts to fulfil human needs.

Table 20
Excerpt 3

Milad	We took pictures that have electronic in them
Xeni	You can use
Milad	Yeah ...and eh ...which are important
George	What?
Milad	Which are important
George	Which are important
Xeni	Should we use these pictures?
Milad	...and which we need
George	Yeah. They are good stuff...
Milad	Yeaah
Xeni	You need to talk to me as well
Milad	...that is needed
George	... which you can drive with
Teacher	Could you tell me about 2-3 artefacts that you have taken pictures of
George	Mobile phone, iPad, charging locker, car
Teacher	Why is this technology?
Milad	Humans have made them
Teacher	What was our thought in the beginning
Milad	That there were electronics in them

In this excerpt, the students are discussing the artefacts they have photographed. Their teacher adds questions in the whole class discussion to promote the students' thinking about their chosen artefacts. Milad starts, in the small group interaction, by stating that the artefacts [...] have electronic in them, which is outlined in the above-presented research as a common perception of technology amongst students. However, it is also apparent that Milad, Xeni, and George jointly elaborate on technology and additionally utilise several of the modes presented by Mitcham (1994), for example, object (mobile phone, iPad, car), activity (Humans have made them), volition (They are good stuff...,...that is needed). Technology as knowledge is harder to recognize in the discussion. Nonetheless, it is possible to interpret Milad's final utterance [...] there were electronics in them as a way of expressing knowledge on how the technological artefacts function to achieve a human need (Kroes & Meijers, 2006). In this case, the students' descriptions, in addition to objects, now refer to all the manifestations of technology.

74 DISCUSSION AND IMPLICATION

In this paper, the aim was to explore how primary school students perceive how technology is manifested. The students take pictures of and talk about technology mainly as objects and micro-technologies, which is in line with previous research, as students often mention different electronic devices when they are asked to identify and describe technology. It is likely that students discuss technology from the perspective of modern high-tech artefacts, functioning through electricity and that this also might be a prevailing discourse in society (Ankiewicz, 2016; Blom & Abrie, 2021; Svenningsson, 2020).

During the interactions and classroom activities, it was evident that Mitcham's typology was too broad. Therefore, it was possible to further evolve the students' interactions by looking at Mitcham's mode technology as objects. As described in the theoretical background, de Vries (2016) divides artefacts (objects) into three subcategories: experience-based, microtechnologies and macrotechnologies. The aspect of microtechnologies is the most common among the students' pictures and in their interactions, for example, laptops and headphones. However, as the technology activities proceed, both experience-based and macrotechnologies become a part of the students' interactions, for example, pencil, and car. The activities between lessons are important because the teacher can create situations where in-depth conversations about technical concepts and the manifestations of technology arise. However, these activities are not primarily the focus of the study.

The findings didactically indicate that by using the tablet's camera as a tool to tap into students' pre-understandings of technology, teachers can construct learning situations in the classroom that build on students' perceptions of technology. This was done by the teacher using the photographs to create interactions that, supported by questions, led the students towards a deeper and broader understanding of technological artefacts. By looking, for example, at Mitcham's technology as object, it can be easier for the teacher to, before the lesson, prepare didactic questions (Why have people created this technology? Why do we need this technology? What do we need to create artefacts?). In this way, it was also possible to add ethical perspectives to technology development. Young students are fully capable of discussing technological objects from various aspects, such as why and how they are created.

Conclusively, the findings suggest that young students, with the support of photographs, interactions, and questioning in learning activities, are competent to develop and expand their understanding of how technology is manifested during activities in technology education. In line with Su and Ding (2022), the analysis of the findings indicates that students can learn and utilise all four manifestations and several subcategories of technology. This means that the teaching and learning activities impact students' understanding of technology as object as well as developing an understanding of technology as activity, volition, and knowledge. Thereby, students develop an expanded understanding of the manifestations of technology.

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Reinventing Secondary School: An Investigation of a Polytechnic High School Model Focused on Industry/Community-driven Design Projects

Deana Lucas, Purdue University, lucas158@purdue.edu
Vanessa Santana, Purdue University, vsantana@purdue.edu
Greg Strimel, Purdue University, gstrimel@purdue.edu

ABSTRACT

Higher education and industry leaders seem to continuously call for transforming the way learning occurs within schools to better meet the needs of students, society, and the workforce. Many attempts have been made to address these calls such as increasing integrated STEM programming in schools, providing after-school robotics activities, as well as developing novel school models. One such innovative model, the focus of this study, is a polytechnic high school model developed in collaboration between a public research-intensive university and several industry/community partners. This model was developed to be implemented in urban settings with an emphasis on serving minoritized youth through design project cycles created with local industry/community partners rather than through subject-specific classes. It can be valuable to investigate a school model that has been created to have this design-based learning approach as its central focus. The purpose of this exploratory study was to understand 1) how teachers perceive the influence of the school model on the learning of students from diverse backgrounds and 2) how teachers view their own experiences working within the school model. This study examined pre/post teacher surveys to provide insights into how the teachers believe the school model is working with respect to students' ability to perform within this style of design-based instruction and any challenges faced by the teachers to implement the school model. This information can help to inform those who seek to provide different learning environments for students through restructuring schools around industry/community-focused design projects. This paper will introduce the components of the polytechnic school model, detail the emphasis of the industry/community-driven design cycles, highlight the methodology used, present some preliminary findings, and discuss insights and recommendations for secondary schooling.

Keywords: Design-based learning, Secondary School Transformation, Integrated STEM Education.

1. INTRODUCTION

Secondary education provides students with a universal foundation of learning through curriculum designed to help every student achieve similar levels of understanding or designated learning outcomes (Leland & Kasten, 2011). To achieve these learning outcomes, schools have established disciplinary silos for teaching subjects like mathematics, science, history, and language arts. This siloed approach has been the dominant way that school's function and curriculum has been structured. However, it can be viewed that siloing of the disciplines deprives, or at least makes difficult to provide, opportunities for students to make valuable and authentic connections between disciplines (Kirwan et al., 2022). According to Kirwan et al. (2022) the siloed educational system can cause inefficiencies in developing well-rounded and thorough instructional resources and curricula, which can in turn have a direct impact on student learning. As a teacher's professional knowledge is linked to education quality and student performance, it can be important to bring more holistic views to the classroom that reflect the multifaceted and interconnected world of today (Evens et al. 2018). Today the challenges our world faces have become more complex, and education can be the key to developing the necessary skills students will need for their careers and lives to work toward these complex problems in the future (Hodge & Lear, 2011). Many countries are calling for the enhanced preparation of students to become creative, innovative, and ready to meet the hallmarks of competitive and emerging industries (Partnerships for 21st Century Skills, 2016). The Partnership for 21st Century Skills (2016) posits that developing skills such as thinking critically to make informed judgements; solving multidisciplinary and open-ended problems; creativity and entrepreneurial thinking; communicating and collaborating; making innovative use of knowledge, information, and opportunities; and taking charge of financial, health, and civic responsibility are a necessary outcome for schools throughout the 21st century. These demands for 21st century skills are also in alignment with the increased attention to the implementation of design-based and/or problem-based learning to support integrated STEM (science, technology, engineering, and mathematics) teaching in secondary schools (Yuxin & Williams, 2013).

There are many theorized solutions to address the demands for 21st century skills through education, such as increasing integrated STEM curriculum to providing after-school STEM programs, or even developing types of STEM focused school models. This study takes a deep dive into one such school model which is an innovative polytechnic high school model that has been developed in a collaboration between a public research-intensive university and several industry/community partners. This polytechnic high school model is positioned to allow students to develop their 21st century skills through integrated STEM learning that provides them with practical training and real-world experience through authentic design project cycles. These design project cycles, some of which are depicted in figure 1, are developed with local industry/community partners and are used as the focus of instruction rather than the traditional subject-specific classes. This model was developed to be implemented in urban settings with an emphasis on serving minoritized youth through this integrated and design-based approach. As integrated STEM learning through design projects has become an emphasis for many schools around the world (Yuxin & Williams, 2013), investigating this polytechnic school model and its design-based learning approach can be valuable for understanding opportunities for improving STEM education.

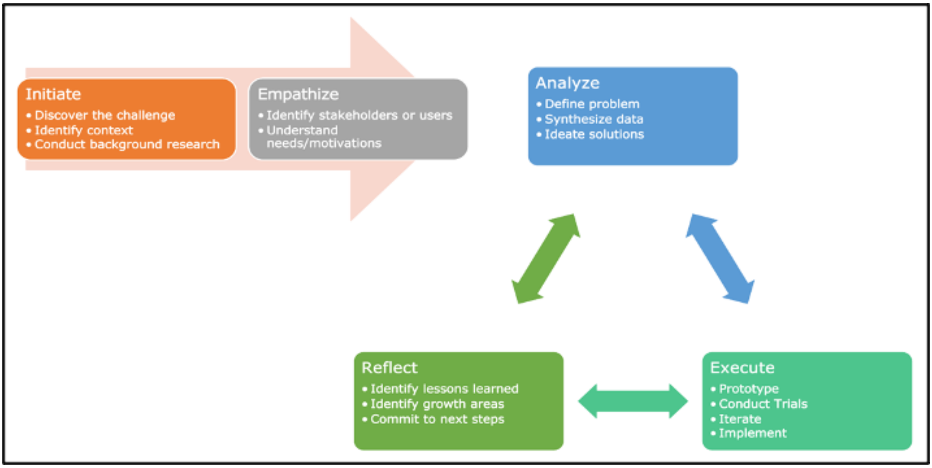
76 POLYTECHNIC SCHOOL MODEL

The polytechnic high school model was designed to integrate STEM learning within personalized learning environments that require hands-on learning (Santana, 2022). Students complete design-cycles every six weeks, where every cycle consists of a different industry or community partnered project, depicted in figure 1. The students are then guided through these design cycles using the school's version of a design process (see figure 2). At the end of each cycle, student teams pitch their solutions to the design challenge to a variety of school, community, and industry stakeholders (Santana, 2022). This design-based learning approach is positioned to encourage students to solve authentic problems that are complex and multifaceted. The teachers, who are referred to as *coaches,* collaborate with industry/community representatives to create the design-cycles in a way that aligns with the academic standards and provide students with rigorous STEM activities that reflect problems or opportunities faced outside of the classroom in the "real world" (Santana, 2022). In addition to industry driven projects, students also can take part in passion projects, which are projects designed by teachers, but chosen based on students' interests (Santana, 2022).

This blend of industry/community partnered design cycles and passion projects take the place of traditional classes usually offered in secondary education such as mathematics, language arts, science, and social studies. Instead of the traditional eight class periods a day, or four classes rotating on a block schedule, this model allows students to establish their own schedules and attend supplemental workshops for obtaining the knowledge necessary for the design cycle and the learning objectives (Santana, 2022). The workshops are referred to as dojos, which are small group lessons that supplement, or address problems related to, a specific topic relevant to the design-cycle (Santana, 2022). When students are not attending a dojo, they are using *personal learning time* (PLT) to work through other educational requirements. The students then use their design-cycle experiences, dojo attendance, and PLT to demonstrate their mastery of the school's core competencies. Then, as Santana (2022) explains, students who graduate from this school with a 3.4 GPA and a 1050 SAT score are admitted into the collaborating university. This school model was founded in 2017, and has grown to be implemented across three schools, with plans for more.

Figure 1.
Example Design-Cycles

Figure 2.
The Polytechnic High School Model Design Process – Note. This graphic was adapted from the school's website.



77 RESEARCH QUESTIONS

The polytechnic high school model is positioned to provide an innovative approach to education to address the demands for 21st century skills and integrated STEM instruction. While this positioning is notable, it is important to study how this school model is being implemented and its potential influence on student learning to enhance our understanding of school transformation efforts. The following research questions were developed to guide this study:

(vii) What are the influences of a polytechnic high school model, which is centered on industry/community-driven design challenges, on students learning (i.e., 21st century skills and sense of belonging) as perceived by the teachers/coaches?

(viii) What are the challenges and successes of a polytechnic high school model, centered on industry-driven design challenges, from the teacher's/coaches' perspective?

78 METHODS

The research questions were answered using data from the 2020-2021 school year that was collected via the school's survey provided in tables 2 and 3 below. Teachers completed these surveys at the beginning of the year, and at the end of the year. To better understand teachers' perceptions of their student's learning, these surveys included Likert-scale items relating to 21st century skills (*Creativity*, *Communication*, and *Collaboration*) and sense of *Belonging*. Additionally, the surveys included open-ended response questions that were used to examine teachers' attitudes toward the school year. During the pre- and post-survey, the duration of years the coaches have been a part of this polytechnic high school were collected as well as their overall teaching experience.

The data from the Likert Scale items were organized and re-worked into numerical values to answer the research questions (“Strongly Disagree” = 1 to “Strongly Agree” = 5 for the 5-point items, and “NO!” = 1 to “YES!” = 4 for the 4-point items). To measure the constructs of *Collaboration*, *Communication*, and *Creativity*, Likert scale items adapted from Kelley et al.’s (2019) 21st Century Skills Survey, were used. Similarly, to measure the construct of *Belonging*, Likert scale items adopted from Anderson-Butcher and Conroy’s (2002) Belonging Scale, were also used. The open-ended questions were coded to find additional themes to support the Likert Scale data.

79 PRELIMINARY FINDINGS

A total of 15 coaches completed the pre-survey and 23 coaches completed the post-survey. The complete demographics are provided in Table 1.

Table 1. *Teacher Survey Participants*

	Years	Pre-Survey	Post-Survey
Teaching Experience	Less than 1	1	2
	1-3	3	4
	4-6	1	2
	7-10	2	2
	11-14	4	3
	15 +		3
Polytechnic High School Experience	Less than 1	4	5
	1	2	3
	2	2	4
	3	1	0
	4	4	4
Total		15	23

During the pre and post survey, results from the Likert Scale questions stayed similar, with some decreases and increases in means and standard deviation. Coaches were asked to select a level of agreement to indicate how they feel about their students' abilities in areas relating to 21st century skills. The survey results are presented in Table 2.

When looking at the responses, the most consistent categories the teachers/coaches felt confident in their students’ abilities, were *be polite and kind to teammates* (mean pre-survey 3.75, mean post-survey 3.60), *improve their own work when given feedback* (mean pre-survey 3.83, mean post-survey 3.60), *acknowledge and respect other perspectives* (mean pre-survey 3.50, mean post-survey 3.80), and *elaborate and improve on ideas* (mean pre-survey 3.50, mean post-survey 3.40). These areas highlight what the teachers/coaches perceive to be their students' strengths with the 21st century skills. During the pre and post survey, there were two categories that scored the lowest, which allows us to gather that teachers/coaches do not feel too confident about their students' abilities to *use time and run meetings efficiently* (mean pre-survey 2.58, mean post-survey 2.55) and *complete tasks without having to be reminded* (mean pre-survey 2.67, mean post-survey 2.55). This polytechnic school model encourages autonomy; however, teachers/coaches may not see that reflected in their students.

Teachers/coaches were asked to select a level of agreement to indicate how they feel about five assertions related to belongingness of their students within the school model (see Table 3). The consistent categories with the highest means were; *I feel that students are a part of this school* (mean pre-survey 3.50, mean post-survey 3.40) and *I feel that students are accepted at this school* (mean pre-survey 3.42, mean post-survey 3.30). One category, *I feel that students are supported at this school* (mean pre-survey 3.50, mean post-survey 3.25), resulted in a high mean from the pre-survey and dropped by 0.25 in the post-survey, which is a larger decrease than all the other means in the belongingness category. As for the categories with lower means, there were two consistently low statements: *I feel that students are committed to this school* (mean pre-survey 2.92, mean post-survey 2.75), and *I feel that students are comfortable at this school* (mean pre-survey 3.17, mean post-survey 3.10). The coaches' views of students' belongings seemed to decline from the beginning of the year. The responses elicited from the Likert Scale questions reveal a little about the successes and struggles of the polytechnic school model. To aid in providing a holistic understanding, coaches were asked open-ended questions as well.

The open-ended questions in the pre-survey asked: *What are you most worried about for this school year* and *what are you most excited about for this school year*. The post-survey questions asked teachers/coaches: *What did you like most about this school year; how would you describe this school to other teachers and what would you feel the need to tell them; reflecting on your experience this school year, what new challenges did you encounter;* and *reflecting on your experience, what could make a student a good fit for this school.* Using the answers to these questions, themes of perceived challenges and successes emerged from the teacher's/coaches' experiences teaching in a polytechnic high school.

Table 2. *Teacher Survey Results related to 21st Century Skills*

Construct	Statement (I believe my students…)	Pre-Survey (*N* = *15)*		Post Survey *(N* = *23)*	
		Mean	**Std. Dev**	**Mean**	**Std. Dev**
21st Century Skills (Collaboration)	are polite and kind to teammates	3.75	1.01	3.60	0.66
	acknowledge and respect other perspectives	3.50	0.96	3.80	0.40
	follow rules for team meetings	3.25	0.92	3.20	0.81
	make sure all team members' ideas are equally valued	3.08	0.86	3.30	0.71
	offer assistance to others in their work when needed	3.42	0.86	3.50	0.59
	use appropriate body language when presenting	3.42	0.95	3.15	0.73
	come physically and mentally prepared each day	2.92	0.95	2.85	0.65
	follow rules for team decision-making	2.92	0.86	3.20	0.68
	Improve my own work when given feedback	3.83	0.69	3.60	0.86
21st Century Skills (Communication)	use time, and run meetings, efficiently	2.58	1.04	2.55	0.59
	organize information well	2.83	0.90	2.85	0.73
	track their team's progress toward goals and deadlines	2.83	0.99	3.20	0.51
	complete tasks without having to be reminded	2.67	1.03	2.55	0.86
	present all information clearly, concisely, and logically	2.92	0.86	2.95	0.64
21st Century Skills (Creativity)	understand how knowledge or insights might transfer to other situations or contexts	3.42	0.86	3.05	0.74
	find sources of information and inspiration when others do not	3.33	1.03	3.20	0.81
	help the team solve problems and manage conflicts	3.42	0.76	3.05	0.74
	adapt a communication style appropriate for the purpose, task, or audience	3.17	0.80	3.00	0.77
	elaborate and improve on ideas	3.50	0.65	3.40	0.73

Note. A Likert-scale of 5-Points was used: 5=Strongly Agree to 1=Strongly Disagree.

Table 3. *Teacher Survey Results related to Student Belongingness*

Statement I believe my students…	**Pre-Survey** ($N = 15$)		**Post Survey** ($N = 23$)	
	Mean	**Std. Dev**	**Mean**	**Std. Dev**
feel comfortable at this school	3.17	0.55	3.10	0.54
are a part of this school	3.50	0.5	3.40	0.58
are committed to this school	2.92	064	2.75	0.43
are supported at this school	3.50	0.65	3.25	0.43
are accepted at this school	3.42	0.64	3.30	0.46

Note. A Likert-scale of 4-Points was used: 4=YES!; 3=Yes; 2=No; 1=NO!

The challenges that emerged were related to the school's curriculum, autonomy of the students, and Covid-19 struggles. These themes which are described in the following sections, were consistent throughout the answers provided to the survey open-ended questions.

79.1 Polytechnic Curriculum

The teachers/coaches mentioned their struggles with navigating the polytechnic school's curriculum. Teachers/coaches found that differentiating their work with the design-based curriculum to meet the needs of all their students was a challenge. One coach had written that they were scared to let "certain academic skills and expectations slip through the cracks" as they navigated the more open-ended projects. The coaches in the school are also given a good deal of creative freedom with the curriculum, which caused some concerns at the school. For example, the coaches worried about not being able to fit important academic topics in the six-week design cycles. Traditional schools typically have a pre-established curriculum given to teachers, usually with some ways to differentiate. However, the polytechnic coaches are following an innovative educational approach that requires more work and agility to adapt and plan for learning without a pre-established curriculum. A saying is that the coaches are "building the airplane while flying it" regarding the learning experiences. Some coaches reported being the only instructor with their background/disciplinary knowledge in the school, and another reported having to learn how to teach two new subject areas in which they were not trained. While these issues may pose challenges for implementing a new school model focused more on open-ended design cycles, some coaches noted the opportunity that this experience brings. For example, one coach mentioned that they are okay with trying out new lessons that they might not have had the opportunity to try before while another coach mentioned that they were enabled to teach more content in which they had a passion for. There are benefits and challenges to this model, and it requires coaches to go outside of their comfort zone. While there is not truly a defined curriculum, the coaches are finding innovative ways to provide students with engaging learning experiences.

79.2 Student Autonomy

This polytechnic school model takes an approach that requires students to hold themselves accountable for their learning. Coaches have seen students struggle with their autonomy. For example, coaches responded that students misuse their autonomy and that the school model "supports a high level of autonomy, and you need to have a tremendous level of patience." The design-cycles reflect real-world problem solving and design thinking scenarios, hence the students are often driving their own progress. The typical classroom dynamics are challenged with this model, and at times, the role of the "*teacher/coach*" needs to shift. Coaches finding the balance in their role while supporting student learning and autonomy, requires change and patience from both students and coaches. One coach described the model as "a non-traditional school, where a lot of the student's academic work is self-paced and online and the school day is split between some classes, independent work, and passion projects." Therefore, "self-motivated, driven students who can work without an adult always pressuring them to complete their work" would be a good fit within this type of school model. However, from the coaches' responses it seems that few students are challenged to fit within this "mold" at their age level.

79.3 Covid-19 Struggles

The survey data were collected at the end of the 2020-2021 school year, which was still amid the Covid-19 pandemic. Therefore, many of the coaches' challenges at the school were centered on this topic. For example, it was mentioned that "the transition from post-covid was hard," getting back from online school to in person school came with its challenges. One of the coaches said they felt "like they are starting from scratch in some ways" at the beginning of the school year, coming back from online school because some students fell "even further behind during the pandemic than other" and another mentioned "this was a challenge this year as we had to spend a lot of time on their basic tasks from a couple of years ago instead of being able to focus on grade level content and up." As students had their classes through a computer screen for an extended period of time, the in-person responsibilities and requirements for a design-based STEM curriculum were hard to translate in a virtual environment. This resulted in a low level of accountability for the students which challenged them in the more "self-directed learning" school model. It was reported that "*from over a year of COVID-learning, students are not prepared to be in a classroom and pay attention with their cell phones and other devices*." Therefore, coming back face-to-face with students, the coaches experienced some challenges for the school model such as dealing with "*behavioural issues due to being under-socialized through eLearning*." One recommendation given by a coach was to have a strong sense of self before teaching in this school model, knowing who you are in an educational model that demands the most from the educator was seen as advantageous in this setting.

While the coaches faced challenges, they also experienced successes in the school. These successes came in the form of student learning and growth, the ability for educational innovation, and the building of meaningful relationships. These themes, which are described in the following sections, were consistent throughout the answers provided to the survey open-ended questions.

79.4 Student learning and growth

Coaches were excited about providing students with authentic, hands-on learning experiences, integrated STEM lessons, and connections with real projects with industry/community partners. Coaches identified that through these learning experiences students were able to pursue their interests in the form of design/project-based learning. Additionally, one of the coaches mentioned how much progress the first-year students made in their design cycle pitches/presentations. Coaches were also "building relationships with the students in order to assist them in understanding their role as a student and a valued and productive member of society." Establishing a positive rapport with the students and assisting them in "crossing the finish line" seemed to allow students to work hard and reach their goals. In an educational model that requires innovation at every corner, everyone is working to learn and grow. The coaches indicated that "the care is so deep at our school for our students. It is really cool to be a part of." The coaches reported their desire to see the students succeed and how education within this polytechnic school goes beyond solely lecturing to students. The coaches believe that within this school students can learn and grow along with their coaches.

79.5 Ability for Educational Innovation

The polytechnic high school model, as per one of the coaches, was described as fostering "*innovation in all areas*." The coaches felt that this school provided innovation opportunities for the students within the learning experiences including innovation opportunities for coaches with decision making related to the school and the curriculum. As this model is new and striving to foster 21st century skills through authentic learning experiences, a coach described this school as a "*pillar for school change*." This innovative educational model is looking to link "*academic connections of why we're doing what we're doing*" to bring context to problem solving through design-based learning. Additionally, the coaches are given "creative control" of their learning activities, and one coach wrote "*I am flexible, innovative, collaborative.*" The coaches are conveying innovation within the school and students are growing through a new type of educational experience. During the design-cycles, the coaches see their role as needing "*to be adaptable to changes throughout the design process,*" indicating that educational innovation for the coaches is constant.

79.6 Building Meaningful Relationships

These surveys were administered during the 2020-2021 school year, therefore some of data are reflective of the Covid-19 pandemic. One of the common themes that coaches wrote about was their excitement to be in-person for this school year. The strain on building relationships between students and coaches was challenging during the pandemic. As one coach wrote, "*I am happy to be back in the building and able to make connections with my students not just in a virtual capacity.*" The coaches want to have meaningful relationships with their students, which is viewed as necessary to help students progress through the design-cycles and their passion projects. Additionally, coaches wrote about the school, saying that "*getting to know the polytechnic high school team, its students, and its philosophy for reinventing education*" was something that they enjoyed about the school year. Forming connections and creating relationships makes a difference in such an open-ended and self-directed educational environment. A coach wrote that "*I am happy that we are all able to get back into the building and be able to work together face to face.*" Overall, coaches were excited for the in-person school year, especially at an innovative school where relationships, innovation, and education come together for hopes of secondary educational transformation.

80 RECOMMENDATIONS AND DISCUSSION

Due to this being the preliminary review of data from the school, the authors recognize there are limitations to the results. However, the data that were reviewed can provide some insights related to school transformation toward a less standardized educational approach. Understanding how the coaches perceive the educational model has the potential to enhance our understanding of the implications related to implementing integrated STEM learning through design project cycles as the central focus of secondary learning. While this school approach can appear to provide authentic, hands-on learning experiences, connections with community/industry partners, a less siloed school culture, practical experiences promoting 21st century skills, and student autonomy in learning, it can also require increased cognitive demands on teachers and students in regard to self-directed learning, minimize experiences with developing disciplinary expertise, and a disconnect with the way in which post-secondary learning occurs. Therefore, further research can be beneficial to better understand the college/career readiness of students experiencing this type of school model as well as their success in post-secondary education. In addition, it can be beneficial to study the implementation of such a school model overtime. For example, the authors have experienced changes in the model since the survey collection and have noticed some shifts toward “more traditional” educational approaches. These shifts can be interesting to determine what works and what doesn’t as well as how educational innovations can be overwhelmed or stifled by cultural/societal norms as these schools do not exist outside of established social systems. Continuing research on this polytechnic high school could continue to provide insight into how less structured schools and design-based learning can be implemented appropriately to support student success.

81 CONCLUSION

As calls for 21st century skills are only becoming more necessary, there appears to be opportunities to transform secondary schooling to better meet the demands of our complex world. Meeting these demands through educational transformation can be challenging as schools exist within complex and interconnected societal and educational systems. Research is key in understanding how educational models, such as this polytechnic school model, function, and influence learning in positive, challenging, and indifferent ways. From the preliminary review of survey results, the data revealed coaches believe students within that school are working respectfully in teams, iterating their work, and most importantly learning and growing. However, it is a challenge to help students manage their autonomy within design-based learning and develop time management skills. Overall, this preliminary review indicates two main perspectives. First, that high school students can struggle with the amount autonomy that is provided through the design cycles and passion projects. And second, that students can benefit from teamwork, collaboration, and relationships with community, industry, and school partners. The information from the preliminary results can be used as an insight into the challenges and successes of a designed-based approach to integrated learning from the coaches’ perspective. Educators, school systems, and other stakeholders can potentially use this information as insight into the polytechnic school model and to inform decisions related to educational transformation.

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The Challenges of Implementing a Spatial Ability Intervention at Secondary Level

Liam Maquet, Technological University of the Shannon, liam.maquet@ul.ie
Urša Benedičič, Technological University Dublin, ursa.benedicic@TUDublin.ie
Rónán Dunbar, Technological University of the Shannon, ronan.dunbar@tus.ie
Jeffrey Buckley, Technological University of the Shannon, jbuckley@ait.ie
Gavin Duffy, Technological University Dublin, gavin.duffy@TUDublin.ie
Sheryl Sorby, University of Cincinnati, sheryl@mtu.edu

ABSTRACT

Spatial skills development has been widely examined throughout the literature, with evidence suggesting many cognitive abilities are malleable and can be improved through targeted solutions. Some previous examples of intervention studies have been shown to reduce the gap between genders, and those of a lower socio-economic status where the training increased spatial ability, as well as in discipline-specific educational performance. These findings align with many national agendas for STEM diversity, which strive to increase participation and performance of such under-represented groups in STEM. With a lot of research being conducted around spatial skill development within a university level setting, or outside of a formal educational context completely, the applicability of such training interventions in a secondary level school context is unclear. With secondary level education aiming to develop many cognitive abilities, including spatial ability as outlined in curriculum documents, the implementation of such an intervention could improve student outcomes and add value to the educational experience of the students. With the time-sensitive nature of secondary level schooling, there are many concerns around the amount of time and effort that needs to be invested to successfully implement such an intervention. Through the piloting of a spatial training intervention, this paper focusses on the development of spatial skills within an upper secondary level setting in Ireland with 358 students aged 14-16 enrolled in the Transition Year programme and their 10 teachers. This paper examines the challenges of implementation of a specific spatial skills intervention, through a variety of lenses, including pedagogy based and performance based, and offers considerations for future research in the area. By looking from both teacher and student perspectives, we explore the issues encountered and offer suggestions to researchers conducting similar studies at secondary level.

Keywords: Cognitive training, secondary level, intervention, student gains, teacher views

1. INTRODUCTION & LITERATURE REVIEW

82.1 Spatial Ability

Cognitive abilities play an important role in developing someone's ability to acquire, process and apply new knowledge (Kautz et al., 2014) and consequently engage in critical thinking (Duffy, 2017). One such ability is that of spatial ability. Spatial ability has gained increasing attention due to its importance in various STEM disciplines (Wai et al., 2009) and real-world applications (Newcombe, 2010), with spatial ability being found as a predictor for participation and success in STEM fields later in life (Uttal et al., 2013). Defining spatial ability is a topic of contention (Uttal et al., 2013) but Buckley et al. (2018) offers an empirical definition based on the CHC theory of intelligence (Schneider & McGrew, 2012). Within this definition, there is the description of various factors within spatial ability itself, including that of visualisation for which there is an evidence base indicating that it is influential of student learning in technology education (Buckley, Seery, Canty, et al., 2018). The recognised importance of spatial skills in technology education is not a new idea and can be seen as an explicit part of Irish curricula (NCCA, 2019). In spite of its clear importance for students' academic success and career choice (Uttal et al., 2013), such abilities are currently underdeveloped in Irish secondary schools (Bowe et al., 2016) and therefore must be further developed with that age group. Technology education especially can be supported by the development of spatial skills, as the subject area demands such abilities within the students. Tasks specific to technology education such as visualising design solutions that do not yet exist, creating and interpreting working drawings, and understanding complex mechanical relationships require such skills. The malleability of spatial skills is known (Uttal et al., 2013), yet the best way to do this is still unclear. Newcombe (2017), when looking at a broader STEM level, proposed two strategies for raising the level of spatial ability. Strategy one focuses on direct training by providing specialized spatial courses to target the skill development. Strategy two however proposes spatialising the curriculum itself by incorporating spatial language, maps, diagrams, graphs, analogical comparison, physical activity that embodies scientific or mathematical principles, gestures, and sketching into teaching.

This study aims to describe and evaluate the process of implementing a spatial ability intervention in secondary level in Ireland. The intervention started in the academic year 2021/2022 when Technological University of the Shannon: Midlands Midwest (TUS), Technological University Dublin (TUD), University of Cincinnati, and the Professional Development Service for Teachers (PDST) collaborated to pilot a spatial professional development program (PDP) for secondary school mathematics teachers. The focus on mathematics teachers is driven by the fact that the PDST took control of recruiting the participants, however the program is appropriate for other secondary school teachers as well as the intervention itself is removed from subject context. The future implications for technology education can already be seen through the tasks being closely related to the skills used in technology education. Examples of this content include orthographic projection, isometric sketching, and symmetry, which can be directly seen through the use of working drawings, design sketching, and functional or aesthetic design. The visualisation skills utilised are associated with the types of activity typical within the technology classroom, such as visualisation design solutions and creating and interpreting working drawings.

82.2 Designing a Professional Development Program

A study conducted in the U.S. identified three core features of PDP activities that have significant, positive effects on teachers' learning (Garet et al., 2001). First, an effective PDP should focus on content knowledge to improve and deepen teachers' academic subject knowledge. Second, it should provide opportunities for active learning to increase teachers' pedagogical knowledge by ensuring that teachers become engaged in a meaningful analysis of their own teaching and form a good understanding of how their students learn. Finally, it should ensure coherence with other learning activities by aligning them with teachers' goals and the official educational standards. The duration of a PDP is also important. Longer activities (with a greater amount of contact hours) are more likely to provide opportunities for in-depth discussion of content, student conceptions and misconceptions, and pedagogical strategies. Activities that extend over a longer period are also more likely to allow teachers to try out new practices and receive constructive feedback (Darling-Hammond et al., 2017). In addition, the established learning environment should be (Bransford, J.D., Brown, A.L. & Cocking, R.R., eds., 2000):

- learner-centred, by acknowledging students' varied backgrounds, skills, experiences, interests.
- knowledge-centred,
- assessment-centred, to make students' learning visible, provide feedback and monitor their progress.
- community-centred, to develop norms in the classroom and connect them to the real world.

The implementation of interventions in educational settings can be quite diverse in nature, and as such there is no set guidelines on how this should be done. This paper aims to investigate the implementation of a specific spatial skills intervention and its associated PDP to identify challenges and opportunities for support in order to optimise future iterations of the programme.

83 METHOD

83.1 Approach and Participants

In Ireland, transition year (TY) and is an optional extra year between lower and upper secondary education. TY can be completed after the initial three years of secondary school (Junior Cycle) and before the final two years of secondary school (senior cycle), primarily focussing on extracurricular activities, and offering "pupils a broad educational experience with a view to the attainment of increased maturity, before proceeding to further study and/or vocational preparation" (NCCA, n.d., p. 2). A quasi-experimental study design was implemented to evaluate the impact on spatial skills of a spatial skills intervention. The study was conducted across a group of 358 TY students (aged 14-16) across Ireland in place of their usual mathematics classes. This sample size was determined by a process of convenience sampling, which was impacted by the recruitment process. The cohort included 152 male and 206 female student participants. Recruitment letters were distributed to schools by the PDST and expressions of interest were then collected from interested schools. Five schools were selected due to the available budget. The control group consisted of 120 participants and the experimental group consisted of 251 student participants (due to errors in filling out test information, while all student engaged with the study and its content, some students could not be assigned to a group for the purpose of data analysis, so their information was not included), with the control and experimental groupings being based on the pre-existing classes within each school. Along with the student participants, 10 teacher participants were recruited for this study but 1 of these later dropped out and was excluded from the analysis. These teachers engaged with a PDP based around the use of the spatial skills course, and the development of supportive pedagogical strategies.

83.2 Materials

The Purdue Spatial Visualisation Test: Rotations (PSVT:R) (Guay, 1976), Verbal Reasoning Test (VRT) (Ekstrom et al., 1976), and math test were administered to all student participants. The PSVT:R provided a measure of spatial rotations. The VRT was used as a control variable for the study by providing another measure of cognitive ability, while the math competency test provided a measure of math ability. All participants completed pre-testing before taking part in the intervention, and post-testing after completing the intervention. All testing was completed on a pen-and-paper basis. Participants were given time limits for each test as follows; 30 minutes for the PSVT:R, 15 minutes for the VRT, and 15 minutes for the Maths Test. Each participant completed the tests individually and under the supervision of the teacher, who reinforced the time limits.

The teacher participants then completed a spatial ability test with an included anxiety test when solving spatial problems. Teachers were also interviewed prior to the first professional development day and once again after they stopped teaching the course. During their teaching they completed short reflective teacher logs after each lesson to assess the quality of the lesson and think of possible improvements. Teacher logs were included in the teacher guide which made it easier for them to fill put since all teachers provided the completed pages at the end of the intervention.

The spatial intervention used was originally developed by Prof. Shery Sorby (Sorby & Baartmans, 2000) for use with third level engineering students, so another aspect of this study is to examine the suitability of the course content for secondary level. It involves 10 modules focussing on different aspects of spatial thinking. It includes modules based on the development of plan views, surface development, rotation of 3D objects about axes, reflection of 3D objects, and more. Although 10 modules are included in this course, only 4 were completed by the students as part of this study. This was determined by the researchers as a sufficient number of modules to complete within the time allocated, that was also provide an adequate indication of success. The modules completed were: *Isometric sketching and coded plans, Flat Patterns, Rotation of objects about a single axis, and Rotation of objects about two or more axes*.

During the intervention, each participant in the experimental group was provided with a physical workbook (Fig .1), snap cubes (Fig .2), and access to a website with interactive software (Fig .3). These resources were utilised throughout the intervention with the teacher in each classroom designing lesson plans for their own lessons. The control group did not engage with the intervention whatsoever and they continued with normal schooling.

Figure 1.
Workbook

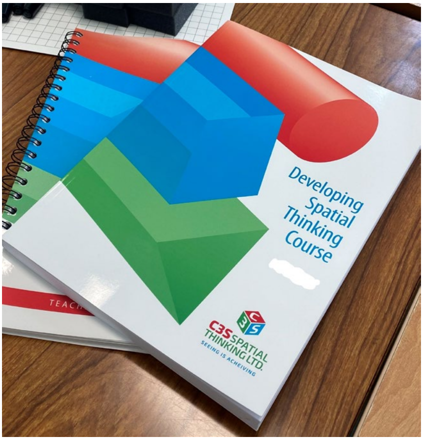


Figure 2.
Snap cubes (a physical manipulative to aid the visualisation of complex geometry)

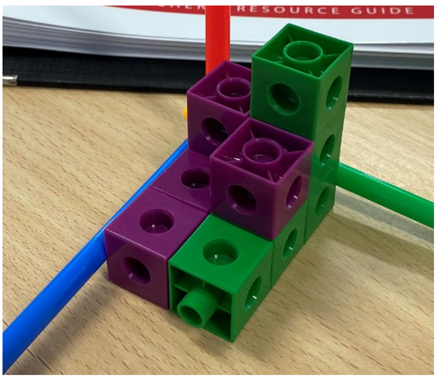
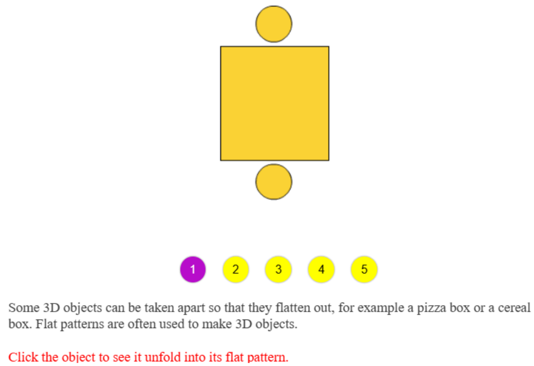


Figure 3.
Sample of the interactive online software provided



83.3 Pedagogical implementation of the intervention

All participating teachers were maths teachers and none of these teachers had any prior engagement with the spatial thinking intervention. Training was provided to teachers before the start of the intervention, as well as continuously during the intervention in the form of professional development (PD) days to ensure that all participating teachers were able to provide an equal level of support to their students. During the PD days, there was a focus on improving the teachers' ability to complete each module, as well as the development of key pedagogical approaches that could be used to implement the intervention. Teachers were provided with a teacher resource booklet, as well as an opportunity for online collaboration throughout the intervention in order to reduce any potential issues in the delivery of the intervention.

84 RESULTS

As this paper mainly focussed on the implementation of the intervention and the challenges surrounding that, not all statistical results will be examined. It is also important to note that this intervention took place over a very short period of time and so the data is merely used to provide indications of future potential. However, an overview of spatial testing performance will be provided to demonstrate some of the preliminary impacts of the intervention.

84.1 Student performance

The control group participants achieved a mean score of 14.62 on the pre-test PSVT:R and a mean score of 14.91 on the post-test. A paired Mann Whitney U test ($W = 883$, $p > 0.05$) indicates that there was no statistically significant difference between pre-test and post-test performance (Fig .4). The experimental group participants achieved a mean score of 15.12 on the pre-test and 16.76 on the post-test, with a Mann Whitney U test ($W = 3266.5$, $p < 0.05$) indicating a statistically significant difference between pre and post-test performance (Fig .4). This suggests that engaging with the intervention had a positive impact on student spatial skills.

When looking at the experimental group alone, male participants achieved a mean score of 17.16 while female participants achieved a mean score of 13.64 on the pre-test. A Mann Whitney U test ($W = 6573.5$, $p < 0.05$) indicates a statistically significant difference among the groups on pre-test performance (Fig .5). On the post-test PSVT:R male participants achieved a mean score of 18.1 while female participants achieved a mean score of 15.9. A Mann Whitney U test ($W = 5982.5$, $p < 0.05$) indicated that there was still a statistically significant difference between the groups after the intervention (Fig .5), however it is interesting to note that the female participants improved more on average in comparison to the male participants, with the intervention being 3 times more effective for females.

84.2 Teacher performance

Teachers engaged in delivering the intervention achieved a mean score of 14 on the pre-test PSVT:R and a mean score of 15.56 on the post-test. A Mann Whitney U test ($W = 2$, $p < 0.05$) indicated a statistically significant difference between pre- and post-test performance (Fig .4). This suggests that taking part in the PD days and delivering the intervention had a positive impact on teachers' own spatial ability as measured by the PSVT:R test.

Figure 4.
Pre-test vs post-test performance among groups on the PSVT:R

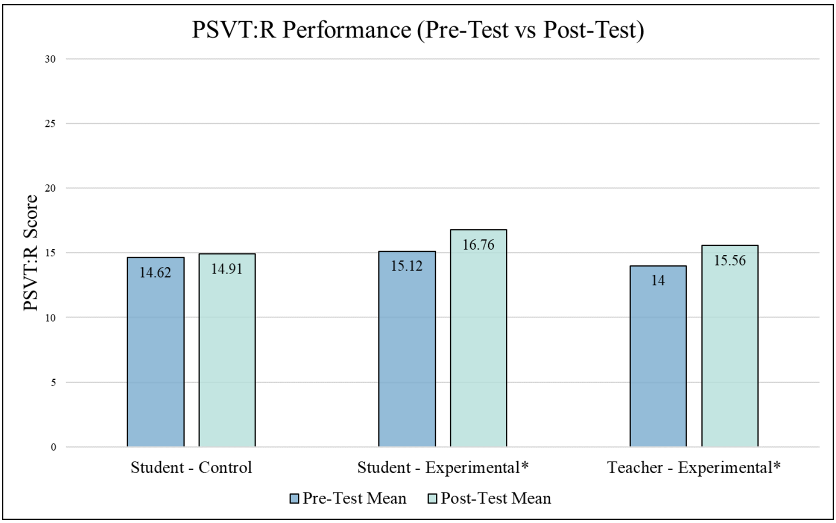
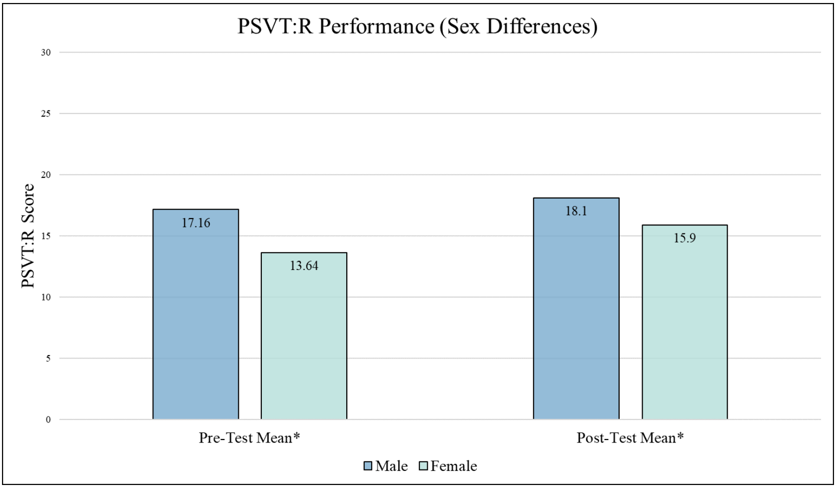


Figure 5.
PSVT:R performance among sexes in pre-test and post-test



85 DISCUSSION

Statistical results described above suggest that engagement in the intervention had a positive impact on student spatial ability as measured by the PSVT:R. This provides a positive indication of future success of the intervention, with the added observational data to support its optimisation. After completing the intervention there was still a statistically significant difference between male and female participants, with male participants outperforming females. What was interesting however was that female participants improved more than male participants, this is something of interest to the researchers and will be investigated in future work.

Through this piloting process, both the researchers and the teachers were met with challenges involving its implementation. This observational and reflective information gathered through discussions with participating partners, teacher, and observation of both PD and practice is more of a focus within this paper and is described below.

85.1 Buy-in/motivation

Attitudes towards the intervention or 'buy-in' was something of noted importance to the researchers, with various aspects to be considered. From the teacher perspective, their own attitudes towards the intervention were quite positive with the majority of the teachers enthusiastic about the prospect of taking this initiative into their own classrooms. This was evident through discussion and engagement levels, which fed directly into the success of the PD days. This enthusiasm however was met with understandable uncertainty, around student engagement and time management of the intervention. Most prominent concerns of teachers were the engagement of their students with such abstract content, as well as the short time span of the intervention and whether this was achievable. However, after the intervention had begun, the feedback from teachers surrounding student engagement was quite positive, with most teachers commenting that their students showed strong levels of enjoyment and engagement throughout their lessons, noting that the content being novel to students supported engagement and interest. One concern raised by teachers was the lack of awareness among students as to the reasoning behind the intervention, with this causing some students to become disengaged as the intervention went on. A possible solution to this problem would be to create a set of resources for teachers to use which highlight the importance of spatial skills, where they are used, and how we can improve them, to ensure student understanding and awareness. Another concern reflected the TY context itself where students participate in regular individualized activities and field trips which effect the class participation and ability to follow the content in the designed order and time span.

85.2 Abstract and repetitive content

As mentioned above the students appeared to find interest in the novel content they were engaging with, however it was discussed that this interest/motivation decreased when they were faced with more abstract content, as they found it difficult to link back to the subject. This decrease in motivation could also occur due to the relatively repetitive structure of the course. If teachers decided to only follow the recommended flow of the lesson without altering its order or adding additional activities to increase its differentiation, students tended to not enjoy its structure as much by the end of it. Through discussions with the PDST, the universities involved, as well as the teachers, it was noted that future iterations of the intervention should place more emphasis on implicit teaching of the content through subject specific resources in order to create a strong link between intervention and subject tasks and ensure that more diverse extension activities and differentiation materials are provided in addition to the established course.

85.3 Order of progression

Another concern raised by teachers was the order in which the modules were presented. These were presented in an order thought to be suitable by the researchers but from engaging directly with students, teachers suggested a more suitable order of progression. Future implementations of the intervention should utilise teacher input when considering the order in which modules should be conducted.

85.4 Teacher professional development

While the PD days were well received by participating teachers, there were suggestions that these should include more discussion and exploration of pedagogical approaches as opposed to focussing on the content. It should be noted that there was a mixture of both included, but the pedagogical discussions were of a descriptive nature. From discussion with the participating teachers, the PDST, and the universities involved, it is recommended that the next iteration of the PD days focus more heavily on explicitly showing and discussing pedagogies to support the intervention, through example lessons and demonstrations, while also allowing time to explore the content itself.

85.5 Establishing a teacher professional community

This study tried to establish a professional teacher community by encouraging teachers to interact with each other throughout the professional development days and ensure there are two teachers from the same school, working with the course at the same time, so they can help each other out when teaching. Also, the spatial website, designed for this study incorporating all spatial materials had a ‘teacher collaboration space’ to encourage more discussion. Unfortunately, this was not used. Possible other ways to elevate the establishment of the community could include in-person meetings. However, these are difficult to plan and execute.

85.6 Teacher and student testing

From the researcher’s perspective, data collection within the study was something that required some improvement. All student testing was completed on a pen-and-paper basis. This made sure that all students had access to the testing (no need for internet access, devices, etc.) but it made data collection both slow and, in some instances, impossible. The collection of paper-based tests in itself is slow, which was expected by the researchers, but the interpretation of handwriting was a more prominent issue than expected with some tests being impossible to read. This is also true for the teacher logs collected. While paper-based tests are useful to ensure access, a hybrid approach may reduce the issues mentioned above. This hybrid approach would allow all students to access the testing, but also streamline the collection through digital measures, however it is unclear how this hybrid approach may impact the validity and reliability of the testing. Another problem with testing can be engagement, especially if there is a lot of it. Engagement with the teacher logs was notably low, which may have been caused by the heavy workload already adopted by teachers when undertaking the intervention. It is recommended that future research is mindful of this, and only necessary data collection is undertaken.

85.7 Student views

When reviewing the intervention, and determining its success as a pilot study, researchers felt that it lacked the student’s viewpoint. Yes, student views were discussed as observed by teachers, but direct student opinions would be useful in the improvement of the intervention. Future implementations of the programme should facilitate the collection of student attitudes towards the intervention.

86 CONCLUSION

Through this paper we can see that the short PDP was effective in preparing mathematics teachers to deliver the novel spatial course, and that the implementation of the intervention lead to the significant improvement in spatial ability. It can also be seen that the results indicate a reduction of the gender gap in spatial ability. This indicates a level of success which supports the motivation for future implementations of the program. The context of TY was suitable for the implemented intervention, and it could be seen that the students engaged positively with the intervention. There are also some aspects which can hinder its efficacy, for example the second half of the academic year becomes busier with field trips, which lowers the attendance rate and in turn engagement levels. The points above provide a snapshot of the critical points identified upon reflection of the intervention. This list is not exhaustive but should be considered when implementing similar interventions within a secondary level setting. Overall, the intervention needs to be flexible and reflective of the context in which it is implemented. These suggestions may offer some support when designing such an intervention.

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Understanding the Head of Department Role: Leading Design and Technology

Paul K. Mburu, Harlington School, pmburuus@yahoo.com

ABSTRACT

In the secondary school curriculum, in England, Design and Technology is to some extent regarded as less beneficial and it is becoming more unpopular with pupils. Therefore, Design and Technology heads of departments find themselves leading a curriculum subject that is in an uncertain situation. The purpose of this study is to consider the perceptions of Design and Technology heads of departments about their practice in monitoring teaching and learning in their departments. This study uses cultural historical activity theory (CHAT) (Engeström, 2001) as a lens to view interview data from six case studies. CHAT is often employed in analyses of activities in workplaces, for example, to uncover how people use both material and conceptual tools and what aspects of tasks they prioritise (Edwards, 2011). Data were collected through field visits that included observations and interviews. The analysis of data reveals how tools were appropriated differently or similarly in Design and Technology department leadership activity systems. The findings identify tools which mediate the work of Design and Technology heads of departments in secondary school. How the heads of departments perceive these tools is analysed to suggest the object of the Design and Technology department leadership activity system. This paper proposes that the contextual settings of subject departments influence department head leadership in forming their own conceptions about their practice.

Keywords: Secondary Design and Technology, school curriculum, heads of departments, cultural historical activity theory, subject department.

1. INTRODUCTION

This paper is derived from doctoral research that explores the perceptions of subject leaders about their practices. The research focuses on subject leaders of Design and Technology in secondary schools for 11-18-year-old pupils. The introduction of the National Curriculum for England and Wales in 1988, define subject areas that establish boundaries around the work of subject leaders and emphasise subject-based teaching (Bennett, Woods, Wise & Newton, 2007). This type of teaching is organised around a subject department, for example, Mathematics, English and Design and Technology. Therefore, it is difficult to separate the work of a head of department from the subject department in which they work (Turner, 2003). For the purposes of this paper heads of department are defined as those specialist teachers who are responsible for a curriculum area. In the educational leadership literature, they are also referred to as curriculum leads, subject leaders, faculty heads, subject coordinators and have a responsibility for one or more teachers that teach an aspect of the academic subject. Heads of departments are influenced by their department's settings, which partly explains the differences in the interpretations and meanings they hold about their leadership practice.

88 LITERATURE REVIEW

88.1 Previous research on subject departments and subject leaders

The subject department are a feature in the organisation of teaching and learning in schools; they are seen to provide the most common organisational vehicle for school subject knowledge (Goodson and Marsh, 1996) and a reference for heads of departments and department teachers' distinctiveness. In most schools in England, a Design and Technology department is a large multi-subject department composed of several independent subjects including and not limited to resistant materials, product design, graphics, systems and electronics, textiles, cooking and nutrition, and hospitality and catering. Therefore, Design and Technology is a confederate department in which a group of subjects share some aspects of teaching and learning; where the head of department is not sufficiently powerful to ensure that the staff members of the department work together on key decisions (Busher & Harris,1999). In some schools, the Design and Technology department is merged with Arts and Design or Information Technology, thus making a larger department.

The importance of heads of departments lies in leading teaching and learning to improve pupils' experiences (Leithwood, 2016). This makes heads of departments responsible for much if not all their colleagues' teaching hence increasing responsibilities in schools and their influence on other teachers (De Nobile, 2018). They aim to support, persuade, and guide subject department staff to achieve the agreed personal, department or whole-school level objectives to support pupil progress. This paper adds to the knowledge base of the practice of heads of departments by considering their interactions in departmental settings. The research also contributes to the understanding of how heads of departments think about their work and why they choose to do what they do.

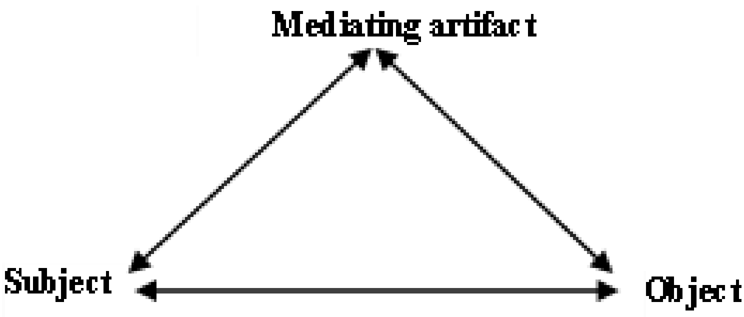
88.2 Design and Technology in the National Curriculum for England

Design and Technology is a complex curriculum subject that has undergone numerous structural modifications. As a distinct curriculum area, Design and Technology was introduced by the Education Reform Act 1988. However, despite the novelty that was intended in introducing a new subject called Design and Technology, unusually the previous technical areas remained as subject specialisms but were in a common design framework (Miller, 2011). The different cultures of various subjects that form Design and Technology, its marginalisation, and the struggle to be seen as an academic subject create distinctive contexts for understanding leadership practice. In this regard, cultural historical activity theory (CHAT) offers a perspective for analysing diverse practices of subject leaders in socio-cultural contexts of departments and across multiple contexts.

88.3 Cultural Historical Activity Theory (CHAT)

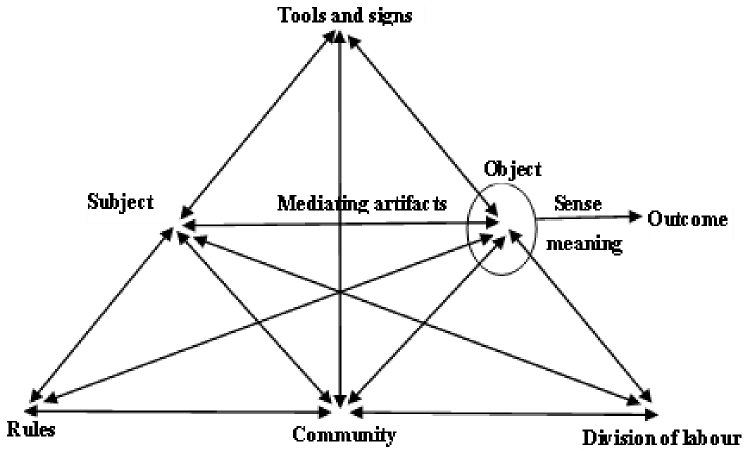
In understanding the approaches in which heads of departments go about their work, CHAT shines a light on the varying and complex forms of human practices, both at the individual and social levels (O'Donoghue and Harford, 2020). These practices are mediated rather than directly affected and regulated by interactions with other people and the world (Lee, 2011). This means CHAT can offer a rich analysis of collective human interactions in context, such as in leading an aspect of teaching and learning in a subject department. The theoretical tradition of CHAT has evolved through three generations of research (Engeström, 1999). The first generation of activity theory, as fronted by Vygotsky is centred on the idea of mediation (Engeström, 1999; 2001). These mediators are how individuals act on and are acted on by the social situation (Douglas, 2015). Vygotsky's greatest contribution to activity theory was that human interactions with the environment cannot be direct but are instead mediated using *tools* and *signs* (Vygotsky, 1980). Vygotsky's mediated action consists of a *subject* or actor, an *object* (either an entity or a goal) and mediational *tools* (Foot, 2014). A contemporary representation of Vygotsky's idea of cultural mediation of actions is commonly expressed as the triad of subject, object, and a mediating artefact (tool), as represented in Figure 1.

Figure1:
Vygotsky's model and its reformulation by contemporary CHAT scholars. (Engeström, 2001, p. 134)



Vygotsky's model of mediated action has been extended to include community, rules, and division of labour, which broadens his idea of mediation (Engeström, 1987). This is referred to as Engeström's second generation of activity theory (Figure 2 below).

Figure 2
The structure of a human activity system (Engeström, 2001: 135)



The activity system model forms a useful bridge between school department structures and the actions of heads of departments (Gronn, 2000). The human activity system is multi-voiced in that it models collective activity undertaken by actors with differing roles, positions and perspectives and is multi-layered; that is, composed of conscious actions and unconscious, routinised operations (Foot, 2014). Through CHAT, the work of heads of departments can be analysed by considering their use of *tools* in the social settings of departments.

A Design and Technology department leadership activity system is created from the perspective of the head of department working in it, others in the department, pupils, parents, and the school community. The head of department, as a *subject* in the activity system, by using *tools* will act on the *object* to produce their desired outcomes. The *subject* constructs the *object* of an identified activity, for example the activity of developing Design and Technology in the secondary school curriculum. There are other activities in a Design and Technology department leadership activity system such as working with parents. This means that an activity occurs through a process that changes the *subject*, the *object,* and the connection between them. *Tool* appropriation is the process of adopting a tool when working on an object (Douglas, 2012). This means that when the subject adopts a *tool* to use, the tool specifies the way the *subject* carries out the action.

Tools can be classified either as material (practical) or conceptual (Foot, 2014). Material *tools* are tangible and could include learning walks, proformas and computer systems used to analyse pupils' data. Conceptual *tools* could include a head of department's knowledge in a Design and Technology specialist subject. When a *tool* is adopted in an activity system it reveals something about the relationship between the *subject* and their *object* at the point at which the tool was appropriated. CHAT recognises that each head of department's professional and personal experiences and their positions in society, work and family influence their construction of the object of the activity (Foot, 2014). Using CHAT offers an analytical lens that can describe, analyse, and facilitate heads of departments' perceptions of practice in a school department and can aid in understanding leadership.

89 CASE STUDY METHODOLOGY

This study's design combined the CHAT framework as a lens to view data and a multiple case study, which allowed the understanding of practice in natural settings (Yin, 2009). The research took a multiple case study design for two reasons. First, it involved professionals in schools with distinctive boundaries. Second, a multiple case design enabled a more in-depth understanding of the cases through a comparison of their similarities and differences. The six participating heads of departments were working in departments that varied in size, culture, location, and context.

Research question: How are tools used and appropriated by heads of departments in Design and Technology department leadership activity systems?

Data collection during field visits involved semi-structured interviews, the taking of field notes (about the settings of the department: department tea-room/office, department corridors, displays around the departments) and the analysis of documents such as minutes of department meetings, learning walks proformas and computer room booking spreadsheets. The range of fieldwork is illustrated on Table 1 below.

Table 21.
A summary of fieldwork from six heads of departments (HoD1, HoD2, HoD3, HoD4, HoD5 and HoD6)

Type of fieldwork	HoD1	HoD2	HoD3	HoD4	HoD5	HoD6
Field visits	1	2	2	1	1	2
Interviews	1	2	2	1	1	2
Duration of interview 1 (in minutes)	65	42	38	43	33	25
Duration of interview 2 (in minutes)	n/a	29	28	n/a	n/a	20
Count of documents shared by the subject leader	2	3	2	4	5	0
Collection of information on Design and Technology department from the schools' website						
Field notes on department classroom walls						
Field notes on display boards on the school corridors.						
Field notes on department tearoom/office						

Following the initial coding and categorising items the research data were subjected to thematic analysis to identify recurring themes (Braun and Clarke, 2006). The data was further viewed from the analytical lens of CHAT (Engeström, 1987; 1999; 2001) which provided a stronger theoretical input than would be possible using thematic analysis alone (Douglas, 2015). The design was a systematic way of understanding leadership practice and CHAT helped to explain why the leadership of these departments was the way it was.

90 RESULTS

The results below are extract from semi-structured interview data from some of the participants about their monitoring tasks in leading teaching and learning.

90.1 Learning walks

The terms 'learning walks', 'walkthroughs', 'informal walks' and 'pop into lessons' were used by participants to refer to the short visits to colleagues' classrooms. Participants revealed that they used learning walks to monitor their colleagues. For example, a judgmental outcome from learning walks demonstrated HoD1's checks on his colleagues.

> I am looking to pick up weaknesses and work out strategies to improve those. (HoD1, interview)

This statement illustrates the judgemental aspect of learning walks. This is supported by HoD1's claim that 'I look through books during learning walks to support decision-making'. HoD1 appeared to use learning walks as a way of identifying areas of professional development for the department staff. HoD2 explained that lesson visits were enabled by the department's open-door policy, a social-cultural practice that facilitated interactions between colleagues in the department. This suggests that HoD2 saw this as a practice that supported monitoring work. This is reinforced by HoD2's view that 'I just walk in and pretend I am making tea' (HoD2, interview 1), which suggests that the purpose of such visits was to monitor colleagues, even though she was reluctant to say to them that she was doing a learning walk. HoD2 thought that this was a less intrusive method (Hammersley-Fletcher, 2002) of monitoring teachers' work. This approach differed from one other participant who purposed and informed colleagues of learning walks.

90.2 Work scrutiny

Participants referred to 'work scrutiny', 'book looks', 'book review' and 'book check' as a task that involved judging the quality of evidence of learning produced by pupils in written, verbal and/or in an artefact form. Subject leaders expressed views that demonstrated their monitoring task in ensuring that pupils' books had teacher's feedback:

> …on-going things like…book check…we share books…just to see what is going on and to see what feedback that has been given (HoD1, interview)

HoD1 explained that book checks were judged based on the evidence that was presented during the exercise. Even though the book check exercise was meant to monitor teaching and learning, HoD2 disliked the idea of ensuring that pupils books were 'up-to-date' for the senior school leaders to check them. HoD2 appears to defend the department staff from the excessive workload that was being imposed by senior leaders. Both HoD1 and HoD2 were of the view that book checks were a routine task, and it was their responsibility to check for evidence of teachers' feedback in pupils' books.

90.3 Lesson observations

Lesson observations were either formal or informal. HoD2 used lesson observations to confirm their views on colleagues' quality of teaching. HoD2 stated that, 'observations, I do it once a term…I know how they teach' (HoD2, interview 1). It appears that lesson observations were a tick-box exercise. HoD1 used lesson observations to identify opportunities that would persuade department staff to share good practice.

> …with the other members of the department [that is] something I have seen in their lesson observations. (HoD4, interview).

HoD1's approach is in line with the view that heads of departments use various sources of power and most successfully achieve their target by working with and through colleagues (Busher, 2005). HoD1's emphasis on the importance of staff being able to share their successes confirms that the central task of the effective head of department is to create a culture of trust in their departmental teams that will make it possible to discuss issues of practice (Bennett, 2006).

91 DISCUSSION

This section applies CHAT concepts in discussing subject leaders' tools and considers how they were appropriated by the participants in the Design and Technology department leadership activity system to achieve an object, thus transforming it into an outcome (Kuutti, 1996). Tools or artifacts mediate subject's work on the object (Lee, 2011). Each participant perceived and took up tools according to their importance to the object of the activity. This take-up of tools leads to creating a possible relationship between the object of the activity system and how the tools are used. Each participant perceived and took up tools according to the importance of the object of the activity in their context. Where heads of departments were seen to work with the staff to improve collective classroom practice; for example, on the quality of teaching and learning in their departments, tools were appropriated for sustaining and developing the work of their Design and Technology departments rather than for monitoring and accountability. This uniqueness is seen in Design and Technology department leadership activity systems where the tool that is the book checks (work scrutiny) was appropriated in multiple ways relating to teaching and learning.

HoD1's book checks were used in a way that was specific to the professional development needs of the department staff. HoD1 appeared to reject the book check tool as presented by the school's senior leaders. HoD1 saw book checks as a way of sharing good practice rather than a tick-box exercise to check conformity. Therefore, the reason for HoD1's rejection of the tool as presented by the school's senior leaders was to emphasise the importance of identifying and sharing good practice amongst the department team. HoD1 saw the book check tool as a way of giving teachers in the department an opportunity to collectively improve their classroom practice. This was achieved through evaluation and discussion of each other's pupils' books. HoD1 used book checks in a developmental way and as an opportunity to encourage teamwork in the department. Although HoD1 was aware of the schools' stipulated use of book checks, they chose to use departmental book checks as a developmental tool to harness the different classroom practices that were exhibited by the staff. HoD1 saw book checks as an opportunity for shared learning between the department colleagues.

Consequently, the appropriation of the tool that is the book check as a means of sharing good practice reveals that HoD1 viewed their role as that of a facilitator of team learning rather than a checker of compliance. By appropriating the tool this way, HoD1 creates an opportunity for sustaining and developing the department. Therefore, the book check tool enabled mediation of the department's work through the head of department. HoD1 was motivated to use this tool this way to refine practice in the department, which contrasts HoD2's view of a similar tool. HoD2 saw the purpose of book-looks as that of checking conformity. HoD2 resisted using book-looks and viewed them as formal, procedural and an unnecessarily inspecting the work of teachers. HoD2 frustration at the lack of flexibility, the numerous occurrences and the approach used in carrying out book-looks could imply that HoD2 saw the book-looks tool as limiting her work in the department rather than as a way of improving the work of the department.

92 CONCLUSIONS

In this paper I have used CHAT as an analytical lens to view data and to illustrate how tools were appropriated in Design and Technology department leadership activity systems. The leadership perceptions that emerged from the interviews with heads of departments were both complex and distinctive in their contextual settings. Heads of departments' view of the object varied depending on the department contexts thus the tools were appropriated differently. The view of the object was different for heads of departments who appropriated tools to monitor and supervise the work of teachers in the department. For example, the tools in such departments were appropriated in a restrictive way; to check compliance and monitor the work of teachers. When appropriated as such, the tools were restrictive in that they acted as rules rather than being used in a developmental way in the activity systems; this is because they were appropriated in a regulatory way (Douglas, 2015). A CHAT analysis of qualitative data has been helpful in gaining an understanding of leadership opportunities in the unique contexts of secondary school Design and Technology departments. Employing CHAT as a lens to view the data enabled an understanding of the different leadership practices that unfold in the social contexts of subject departments.

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Problematising and Unpacking the Uncertainty of Design within Technology Education

Manus McDyer, Technological University of the Shannon, a00302279@student.ait.ie
Jeffrey Buckley, Technological University of the Shannon, jbuckley@ait.ie
Rónán Dunbar, Technological University of the Shannon, Ronan.Dunbar@tus.ie
Nicolaas Blom, University of Limerick, nicolaas.blom@ul.ie
Niall Seery, Technological University of the Shannon, niall.seery@tus.ie

ABSTRACT

Technology education is a growing field internationally where developments are being made to conform to new agendas and goals of today's society. The role of technology education is to improve the quality of human life through making meaningful advancements to our lives and the world we live in, which is underpinned by an innate ability that all humans possess, the ability to design. Developing designerly members of society that have strong design capability is identified as being of upmost importance, particularly within education. Fostering designerly students effectively and successfully is a complex domain and is evident within a large literature base, where researchers are trying to understand design, what it should look like in practice, and how it can be successfully developed and fostered within education. Design is a key component within technology education curricula, where teachers and students are required to engage in design tasks and activities in an attempt to foster an ability to design. Design is highly complex in nature and with ambiguity within the literature surrounding the construct of design ability, what defines the design process and what cognitive processes are necessary to design, leaves educators and students in an area of unknown. In this paper, a theoretical model is presented and utilised to problematise and unpack the uncertainty of design within technology education. The unknown of designing is worse than the problems themselves, which is why this paper offers an initial attempt at identifying these problems through the lens of understanding, teaching and learning designing. Results offer insight into the complexities and challenges associated with designing in technology education with the aim and objective to identify future research areas.

Keywords: Design, Designing, Technology Education, Problematising

1. INTRODUCTION

Technology education, which is considered to be an internationally valued subject area within secondary education curricula (Buckley, 2023), is a growing field of research (Buckley et al., 2022; Williams, 2013, 2016; Xu et al., 2020). Technology is a core element of society where its aim, as defined by Black and Harrison (1986 as cited in Hope, 2013), is "to improve the quality of human life" which partly forms the necessity of technology education. Looking at where technology education stemmed from, specifically within the Irish context at least, it is rooted within vocational education designed in response to local industry needs where craftsmanship values and skills were at the heart of the suite of subjects (NCCA, 2017) . Today, technology education is continuously growing in response to the overarching complexities, goals and values of a technological society relating to, for example, sustainability and technological advancements. Providing an education system which develops learners as valued members of society whom possess key skills and abilities that will be the heart of successful development and progression of today's made world is of critical importance. One of these core abilities that has seen a growing emphasis and treatment within technology education is design, where researchers such as Stables (2008) and Baynes (2008) argue for the necessity to develop design capability and the designerly in young people. Design education has been within secondary level education since the 70s and 80s with its seminal research still with importance and relevance today (Baynes, 2008). The development of design education since then is caused by the necessity to conform to new agendas and goals of this developing world (Baynes, 2008).

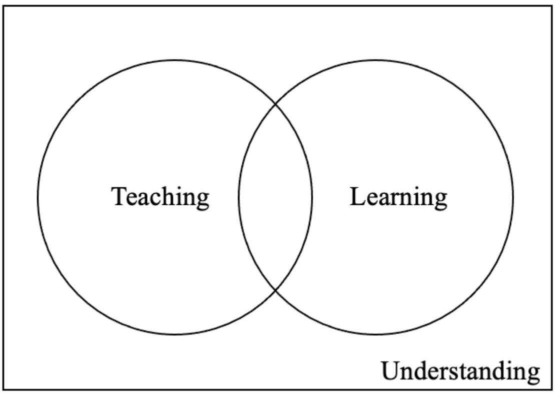
Design is a heavily researched area, but this does not directly correlate to an agreed consensus on the treatment of design, how it appears in practice (Alison et al., 2022; Buckley et al., 2020) and even through universal definitions of its many facets. As Baynes (2008), describes where there is consensus is that design is complex, highly specialist and esoteric, and design ability is innately part of every human being. It is also understood that design is integral to the discipline through the means of teaching to and through design (Buckley et al., 2020; Seery et al., 2022). The recent Irish reform of the Junior Cycle (lower secondary level education) has seen an enhanced treatment of design within technology education and these advances can also be seen within the literature situated in the United Kingdom where Spendlove (2017) argues for a greater emphasis to be placed on design. The large body of literature investigating the many facets of design and the development of its position in practice, cannot be mistakenly understood that there is no ambiguity in its treatment in practice (McDyer et al., 2022). Atkinson (2017) discussed that the emphasis on design within technology education syllabi is problematic as there is no common understanding amongst educators of what design is, what it should look like in the classroom and how it should be taught.

As educators we are preparing our students to be successful citizens for future societies within an unknown – or at least unpredictable – world. Designerly ability has been and will continue to be a core attribute to the advancement of human beings and of our society (Baynes, 2008). With such variance in understanding design, what it should look like in practice and lack of consensus in the definition of its many facets, the question of how we can successfully foster designerly students' merits posing. In response to this question and the associated agenda of qualifying the positioning of design within technology curricula, a theoretical model is presented, designed to support the unpacking of the complexities and intricate nature of designing in education. Through it, we identify and discuss the problems and challenges associated with designing to support future research. Thus, following this introduction will be the identification and unpacking of key problems as we see them associated with designing in technology education, followed by a discussion where the model will be clarified and elaborated upon based on its intended use. The focal research question which will be explored through the paper is, what are the problems and challenges associated with fostering designerly students within technology education?

2. PROBLEMATISING AND UNPACKING THE UNCERTAINTY OF DESIGNING IN TECHNOLOGY EDUCATION

Presented in the body of this paper are the identified focal problems that have been unpacked using one iteration (Fig. 1.) of the theoretical model described fully in Fig. 3. This model consists of three co-related strands which are *Teaching*, *Learning* and *Understanding*. Underpinning this model is the fluid relationship between the three strands, where each of them will have a direct impact on the other two i.e. if a problem was identified in a specific area of learning to design, then this will impact teaching to design which will also impact teachers'/students'/researchers' understanding of design. The discussion section of this paper will clarify and justify the creation and design of this model following these identified unknowns and problems of designing. These challenges and problems discussed have been identified and unpacked through understanding the relevant literature base and supported from the knowledge and experiences of authors in teaching and learning design in the context of technology education at secondary level. These include; what does design look like in practice?, classroom-based problems, complexity of studying design, emerging pedagogies, design studio, varied understanding of design and how can we become better designers?

Figure 1. One 'iteration' of the theoretical model unpacking design to support the identification of problems and future research activities. This iteration looks through the lens of designing in secondary technology education.



2.1. What does design look like in practice?

Teaching and learning designing is challenging, and this challenge can be amplified by the ambiguity in the definition of design and the varying processes of designing (Stables, 2020). It is understood that design invokes variance in practice (Atkinson, 2017), which concerns its 'teachability' and 'learnability' (Seery et al., 2012). One of the complexities of design is that its construct is synonymous with a breath of perspectives and constructs (Seery et al., 2022) that will see the treatment of design vary amongst contexts, and disciplines. Design is also interdisciplinary, for example, there is product design (Morris, 2016) and engineering design (El Maraghy et al., 2012) to name just two, which by nature will have varying goals and agendas that will foster a contextualised outlook on design for that discipline. The interdisciplinary nature of what could be considered as design within professional contexts is one reason as to why design holds varying interpretations in secondary level, general education, contexts.

What is problematic for technology education within the Irish context is that there is no understanding of what it looks like in practice. There is of course anecdotal understandings and qualitative investigation into how it can be treated (Doyle et al., 2019), but there has not yet been any empirical work which examines how design is treated nationally in a representative and descriptive manner. The unknown is a larger problem than the possible variance itself, and what could be argued is that the unknown must become known in order to progress design within technology education. Additionally, from the understanding that design is interdisciplinary, investigation into the comparison of design within different subjects within the technology suite in Ireland would be necessary to respect the individualities of the subjects and the nature of design. Applied Technology (NCCA, 2018a) , Engineering (NCCA, 2018b) , Graphics (NCCA, 2019) and Wood Technology (NCCA, 2018c) at lower secondary level and Engineering (NCCA, 1983), Construction Studies (NCCA, 1984), Design and Communication Graphics (NCCA, 2007a) and Technology (NCCA, 2007b) at upper secondary level make up technology education in Ireland. Each subject with individual goals, agendas and learning outcomes raising the importance to uncover how design is treated across these subjects.

2.2. Classroom-based problems – design fixation and design feedback

Design fixation, which is the blind adherence to a limited set of ideas (Jansson & Smith, 1991), is a problem found within second level students designing (Schut et al., 2020). Design fixation stems from creative blocks (Schut et al., 2020) and personal and emotional attachment to one's own designs (Baer & Brown, 2012; Schut et al., 2020), resulting in hampered convergent and divergent thinking and ultimately less creative and complete design solutions (Schut et al., 2020). Most commonly, design fixation is found at the end of the design process where 'stereotypical' designs are identified (Nicholl & McLellan, 2007). Schut et al. (2020) has identified and investigated successful strategies to support the identification of fixation early in the design process through conversations and interactions with students, however problems and challenges occur with providing feedback and support to guide students out of fixation.

Epistemic uncertainty is integral to design where designers are working on the extremities of their current knowledge (Schlosser & Paredis, 2007), which raises further complexity to the support and guidance needed when designing. A lot of valuable work has been done where interventions have been developed and tested where results indicate that implemented design feedback interventions can successfully guide young learners into engagement in constructive feedback dialogues through divergent and convergent thinking (Schut et al., 2022). Feedback conversations should be constructed carefully, as they are sensitive and filled with fragile egos, sensitive identities and insecure learning processes (Schut et al., 2022). Critical thinking is seen as an integral and essential part of technology education (Williams & Stables, 2017) and as Schut et al. (2020) describes critical thinking and critical reflection as a process to limit and mitigate design fixation and essential to the accepting or rejecting of feedback in order to explore its merit without bias (Schut et al., 2022). Schut et al. (2022) has found that feedback is problematic in nature because of the need for students to have a strong critical evaluation skills to balance openness and persistence when met with criticism on their personal design. This challenge provides problems for both students and teachers in overcoming fixation and ensuring the correct guidance and support during the design process.

93.1 Complexity of studying design

Strimel et al. (2020) undertook an investigation into design cognition research to integrate the findings from multiple studies to develop more formal and generalised theories that would provide deeper and more powerful understandings of student design thinking to bridge the gap between research and practice. Findings identify problematic traits of studying design such as the context of the study, the design task itself and the coding schemes using to interpret findings. These constraints on studying design led to varied results and conclusions being drawn which cannot be generalised due to the nature of design. For example, one study found that the most dominant cognitive process when designing was modelling/prototyping, which contradicted another study whose most dominant cognitive processes were analysing and design. Strimel et al.'s (2020) integration and synthesis of these findings found that the first study's design task was to provide a physical prototype as the outcome, where the later study's design task outcome was to produce a conceptual design. This finding identifies that different design tasks afforded different conclusions which evidences the lack of capacity for generalisability and transferability in at least this stem of design research. This emphasises the complexities of studying design and the impact that constraints on the design and implementation of design tasks has on the study's results.

2.3. Emerging pedagogies

Vital to the success of designing in technology education is the development of effective and validated teaching and learning pedagogies that can be successfully adopted into the classroom. There exists a large literature base exploring emerging pedagogies, but even with such an extensive knowledge base, problematic conclusions can be drawn. To support the exploration of this problem, the emerging pedagogy 'Learning by Design' (LBD) will be discussed. LBD is an inquiry-based approach to learning based off two pedagogies that are 'problem-based learning' and 'case-based reasoning' where students learn concepts and skills through their own identification and self-motivated learning and reflection (van Breukelen et al., 2017). Theoretically this approach provides students with rich learning environments where self-directed learning takes place through design tasks (van Breukelen et al., 2017). Van Breukelen et al. (2017) found that students learn just enough for design-implementation and solution outcome rather than developing a true understanding of the underpinning concepts for intended learning. Identified future research focuses on the interaction with teacher's where the key concepts are explicitly discussed and that the design task is simplified without diluting the key learning. This raises the question whether this possible adaptation into practice dilutes the underpinning value of the pedagogy outlined in the theoretical findings?

What is problematic are the unknown complexities of these pedagogies and the constraints and difficulty in their implementation into practice, moreover, this identifies and emphasises the complexity of teaching designing.

2.4. Design studio

To add more complexity to the teaching and learning of designing is the studio or the environment in which the designing takes place. Chen (2016) investigated the learning problem and resources within the design studio where results found that students rely heavily on interaction and communication with instructors, peers and the internet to solve problems. These interactions are not problematic by design and can provide fruitful guidance (Chen, 2016) but as identified previously these interactions such as teacher-student feedback has its own complexities in order for it to be successful in supporting designing. A negative attribute of using the internet to support the design process was that it was found that students more regularly copied ideas and designs to solve problems, which delegitimised this tool as an effective support mechanism for design, due to students' lack of knowledge and or understanding of its value in supporting their design capability (Chen, 2016). This problem of the incorrect use of teaching and learning tools within the design studio emphasises that within learning to design, the misuse of tools and resource can negatively impact the learning intended.

2.5. Varied understanding of design

The unknown understanding of design and its variance in practice is problematic within the literature and it can be argued that this same ambiguity can be seen in the classroom. Crismond and Adams (2012) stated that young students perceive a design challenge to be a well-structured problem with correct and incorrect answers, so they attempt to solve it immediately. What we see from the literature base is that many researchers identify design to be ill-structured, with a high degree of freedom in its representation, processes and solutions (Jonassen, 1997). The students' interpretation of a design problem is not the problem, but rather the identification of the variance in how design is understood, and whether students understand the role of ill-structured design problems. Well-structured problems support students in applying skills to varying situations of similar degree and context rather than developing their problem-solving or design skills through higher degree tasks which are more meaningful to learners outside of the classroom (Jonassen, 1997). As stated earlier, there is no evidence that identifies teacher's understanding of design with the Irish context, which could provide rich insights into design in technology education

2.6. How can we become better designers?

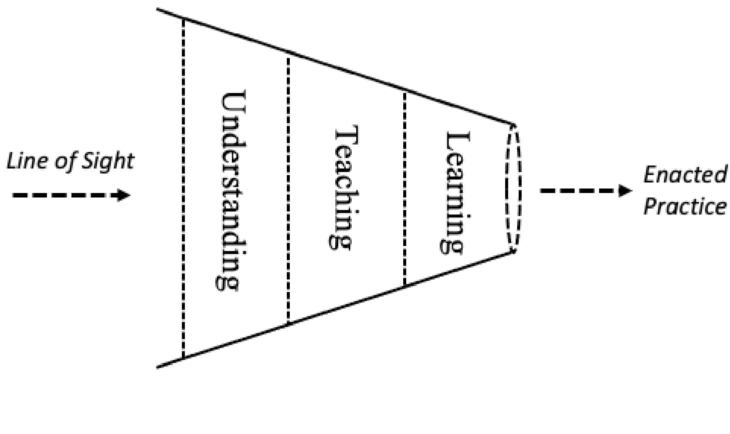
The final problem identified in this paper, can be argued as being the most complex in nature due to the complexities of the construct of design. Every human being is innately designerly by nature (Stables, 2008) but what is not understood is exactly what is the makeup of being designerly? Design capability has been argued as being the skills, knowledge, motivation, ability to bring future possibilities into reality through thought and action (Stables, 2012). Design competence, has been conceptualised as a social activity, knowledge and information processing, structure building and as a non-verbal process (Dorst, 1995). However, attempting to conceptualise and understand design ability results in questions of such nature as, is there such a construct as design ability? Buckley et al.'s (2020) synthesises of a body of literature with the intention to inform the structural alignment of design ability outlines the multiple complexities to understanding this potential construct. There is ambiguity surrounding the measurement of design ability (Buckley et al., 2020) and so how can the investigation of fostering design ability take place if there is no consensus to its accurate assessment. For instance, if a beginning secondary education engineering class's design task was compared against an end secondary education engineering class's design task, excluding the obvious difference in skill and knowledge base, what would the difference be?

What is problematic with designing within technology education is that there is no universal definition on the construct of design ability, and so challenges the practices of fostering designerly students.

3. DISCUSSION

Presented in Fig. 2 is a graphic representation of the relationship between each of the elements underpinning the model (Fig. 3). Using the analogy of a telescope, looking through the lens (ones perspective) the first element that will be seen is understanding, followed by teaching and finally learning. The funnel shape and linear layout of the elements describes that learning is impacted and underpinned by teaching, which is ultimately fostered from understanding, i.e. one must conceive design, in order to teach towards it, so intended student learning can take place.

Figure 2. Looking through the 'telescope' to understand the relationship between each strand of the theoretical model.

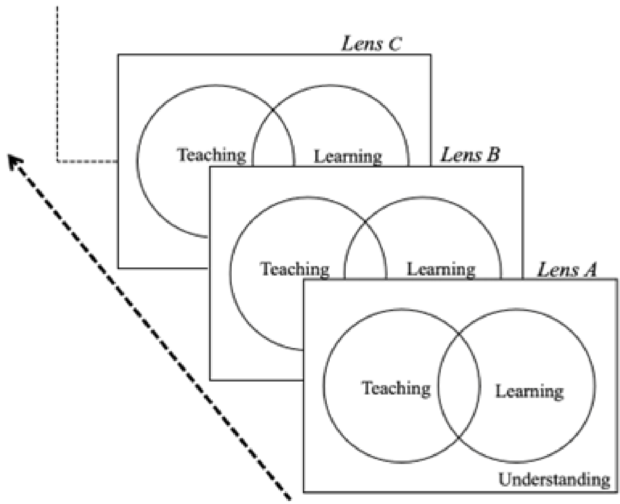


To the fore of problematising the uncertainty of design within technology education in Ireland is the establishment of the theoretical model presented in Fig. 3 and specifically, the use of one specific iteration shown in Fig. 1. This theoretical model was designed and developed through the lens of a practicing engineering teacher where key components to practice were identified and used as elements to the framing of the model. The elements are understanding, teaching and learning. At the core of education is teaching which is underpinned by understanding both within educators' own knowledge base but also that of the literature, ultimately impacting on student learning. What is key to this model and encompasses the complexities of design is that the model will have different iterations depending on the lens in which you look at the model. This is an attempt to interpret the nature of understanding. There is an undetermined number of lenses from which one can view the model that will be dependent on the context of design, the persons understanding and role as a teacher/researcher/student. Practicing teachers' fostering of designerly students in secondary level technology education was the lens, i.e. iteration of the model, used to problematise design in section *2* (Fig.1.). To further describe the value and intended use of this model a short hypothetical vignette will be used describe the nature of understanding, teaching and learning, to provide an insight into how it fostered the identification and unpacking of the problems described in section *2*.

> I am a secondary education engineering teacher in Ireland. To prepare for teaching my students I must become familiar with the subject specifications. Recently the Junior Cycle has been reformed that now sees a new treatment of design within technology education. My understanding and interpretation of the syllabus is that I must develop a learning environment where design application is a core element and students must understand the design process and be creative about forming their design solutions to design challenges. Immediately this challenges my understanding of design, how it is defined, what it looks like in practice, what are the core elements of the design process and what is the most effective pedagogy to foster student designers. I discussed these questions with my colleagues but they teach Graphics, Applied Technology and Wood Technology, which each have different treatments of design. A wide literature base that I am unfamiliar with adds further complexity to selecting necessary pedagogies and tools. I must select and design the necessary assessment strategies to ensure students are developing their designing skills in my class. I have 3 classes of engineering with a wide range of student abilities, skills, knowledge and learning needs, which adds further complexity and challenge to my understanding of design, and specifically what it looks like in my context.

This hypothetical vignette serves as a tool to describe one lens in which design was unpacked using the theoretical model (Fig.3. and this lens' iteration in Fig.1). The lens will depend on the nature and context to which the person is situated within and the complexities of the nature of understanding.

Figure 3. Theoretical model to support problematising the uncertainty of design underpinned by the interpretation of the nature of understanding, where the lens forms an iteration of the model dependent on the perspective/context that design is being understood.



4. CONCLUSION

This theoretical model presented is a naïve theory based on problematising the uncertainty of design within technology education. This paper is an attempt to describe the complexities of design within technology education and identify the wide literature base that exists. Future research will include investigating teachers' perceptions of their understanding and confidence in fostering designerly students amongst other studies based on the areas discussed.

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Technological and Engineering Design Based Learning: Promoting Upper Elementary Graphical Device Comprehension

Cheryl E. Morgan, W. W. Robinson Elementary School, cemorg78@vt.edu
John G. Wells, Virginia Tech, jgwells@vt.edu

ABSTRACT

The research presented is an investigation into the use of technological and engineering design based learning (T/E DBL) as an instructional strategy to facilitate student comprehension of nonfiction/informational text inclusive of graphical devices. The research design followed a mixed method exploratory embedded case study. Six 5th grade participants were examined as both a whole group and as reading level dyads (below, on, and above grade level) as they progressed through three T/E DBL challenges designed to intentionally support graphical device comprehension (GDC) instruction. Data were collected from a variety of instruments used to assess participant prior knowledge, comprehension of graphical devices, and resultant reading comprehension of both familiar and unfamiliar texts. Analysis of data generated detailed descriptions of the reading comprehension levels for each participant throughout the study. Findings indicate that T/E DBL increased text interactions and graphical device usage across all participants, promoted their development of general GDC for diagrams and tables, improved their comprehension of unfamiliar science texts, and proved to be of particular benefit to below grade level readers. These results demonstrate the viability of T/E DBL as a valuable component of elementary level reading instruction for improving student use and comprehension of graphical devices, and for improving their overall comprehension of unfamiliar science and engineering texts where embedded graphical devices present new content in a visual information genre.

Keywords: Design Based Learning, Graphical Device Comprehension, Reading Instruction, Science Comprehension, Engineering Comprehension

1. MOTIVATION

Throughout the past two decades, the role of nonfiction/informational text within K–12 literacy instruction within the United States has undergone significant changes in an attempt to meet the current national educational needs (National Governors Association & Council of Chief State School Officers, 2020). As needs, practices, and goals within education change, the National Assessment of Educational Progress (NAEP) adjusts its development of assessment guidelines to establish national baseline assessment expectations (NAEP, 2019). Although the NAEP emphasis on nonfiction texts has significantly increased over the past decade, recent national test scores indicate that comprehension of nonfiction/informational text continues to be a particular weakness. In spite of this increased emphasis, the current weak performance of U.S. students on standardized nonfiction/informational reading assessments raises serious questions about best practices for nonfiction/informational text comprehension instruction.

Reading instruction within disciplines and/or using discipline-specific texts calls for disciplinary-specific literacy instruction. Disciplinary literacy acknowledges the discipline as a whole, and recognizes that form (genre) will follow function (the discipline) – "one learns how to read or write a genre through experience with that genre" (Duke, 2000, p. 206). Specifically, the situational (contextual) interpretation of discipline-specific text is critical to constructing an understanding of the concepts within that text. As such, educators in a specific discipline must design contextual experiences that require students to "engage, elicit/engineer, examine, and evaluate" the language within the discipline in order to develop disciplinary literacy (Moje, 2015, p. 260). The complex structures of discipline-specific informational/nonfiction text are not the only impediments to nonfiction text comprehension.

One such barrier is limited student interactions with informational texts in the classroom (Duke, 2000). Even more problematic is the inclusion of graphical devices. Graphical devices are images (structures) within texts that serve as a means for introducing new information and/or concepts through a visual structure such as: diagrams, flow diagrams, graphs, timelines, maps, tables, images, and simple photographs. However, due to their visual nature, graphical devices are not processed and understood by students in the same way as other nonfiction text features (Poivio, 1971; Sadowski & Paivio, 2001; Roberts et al., 2015).

Graphical devices are an integral part of both science and engineering disciplines and their disciplinary texts. Despite the intrinsic role graphical devices play in engineering, currently no research exists on how authentic engineering activities may support graphical device comprehension (GDC). This constitutes a significant gap in the research on discipline-specific reading comprehension instruction demonstrated to better prepare students to evaluate the unique languages within a given discipline.

One promising and overlooked avenue for enhancing GDC specific to engineering at the K-12 level is the use of authentic technological and engineering design-based learning (T/E DBL) experiences. T/E DBL is a pedagogical approach that intentionally teaches the content and practices of STEM disciplines. Immersing learners in T/E DBL imposes on them the need for higher-order thinking while engaged in designing T/E solutions where they "design to understand" (Wells, 2016a, p. 15). Within this context, the research presented in this paper examined the use of T/E DBL challenges as a strategy for facilitating student comprehension of nonfiction/informational text wherein the inclusion of graphical devices provides essential disciplinary information.

1. THEORETICAL FRAMEWORK

1.1. Graphical Device Comprehension (GDC)

Reading comprehension research encompasses a diverse set of theoretical, empirical, and pedagogical approaches that require a clear and comprehensive definition of reading comprehension. For the purposes of this study, reading comprehension is defined as "an active process that involves using knowledge of written text, language, and the greater world to create meaning through mental representations of the text" (Morgan, 2022). This definition combines that of the Rand Reading Study Group which states that reading comprehension is "the process of simultaneously extracting and constructing meaning through interaction and involvement with written language" (Snow, 2002, p. 11) with the emphasis on prior knowledge and situational interpretation of the text in Kintsch's Construction-Integration model. It is important to acknowledge that the term "written text" in this study's definition includes both continuous text and graphical devices.

Graphical devices are images whose inclusion in texts contributes to the overall purpose of the text by contributing information unique from the continuous text (Fingeret, 2012). Roberts et al (2015) proposed that the distinct process of understanding the purpose of a graphical device, understanding how to use different graphical devices to extract information, and the ability to explain the information within the graphical device can be called graphical device comprehension (GDC). As such, GDC will significantly contribute to a reader's overall comprehension of a text that includes both continuous text and graphical devices. A complete understanding of GDC and the role it plays in reading comprehension begins with understanding the theoretical underpinnings of how literacy of visual elements differs from the comprehension of written text.

1.2. GDC and Elementary Nonfiction Text Comprehension

Paivio's Dual Coding Theory, the Cognitive Theory of Multimedia Learning, and The Integrated Model of Text and Picture Comprehension all propose that verbal (language-based) information is processed differently from visual information and how mental models are formed (Paivio, 1971; Sadowski & Paivio, 2001; Mayer, 2005; Schnotz, 2005). Therefore, given GDC and comprehension of continuous text are achieved through different processes, the distinctions between the two types of comprehension must be considered when examining instructional methods of reading teachers. Specifically, GDC must be considered within the greater context of how it contributes to overall reading comprehension of nonfiction texts as a whole. This is particularly significant given the unique information contained in graphical devices and the requisite understanding of the graphical device in order for the reader to fully grasp nonfiction text (Fingeret, 2012; Guo et al, 2018).

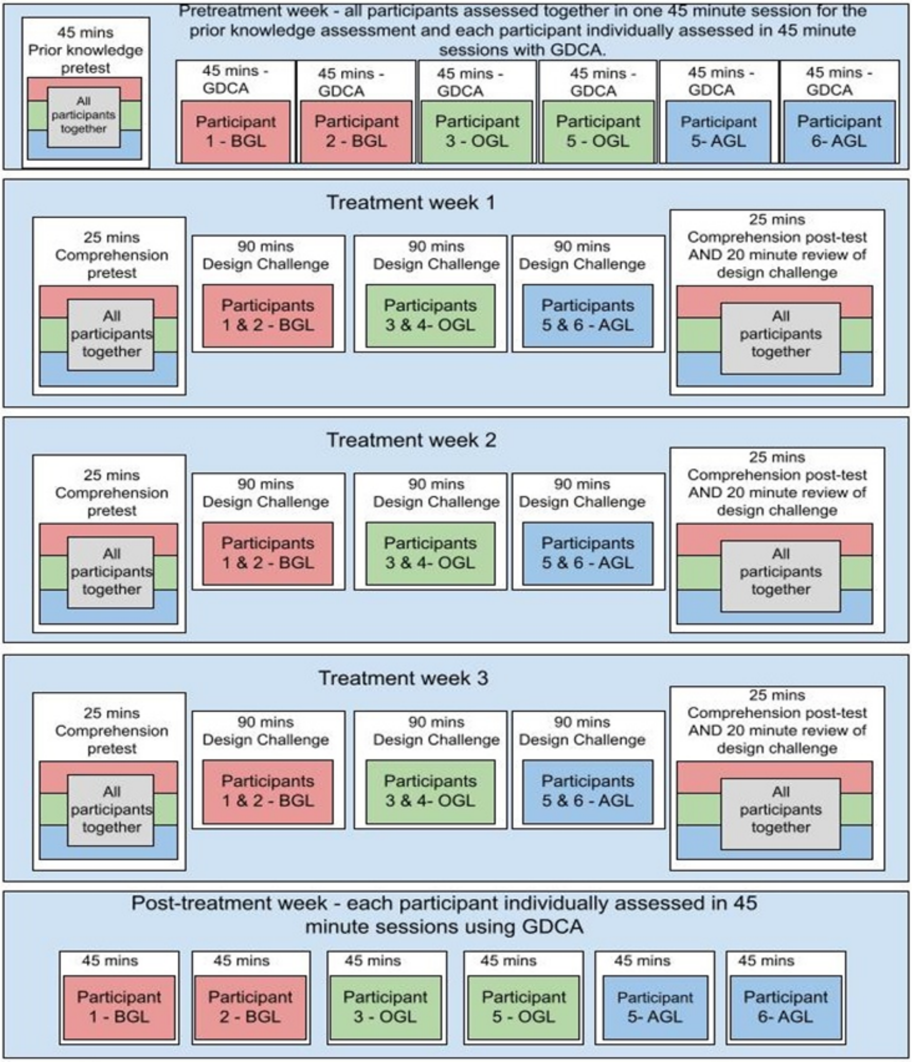
A close examination of the research literature indicates there are multiple potential issues regarding comprehension of graphical devices embedded in nonfiction reading comprehension. Readers often fail to acknowledge graphical devices (Hannus & Hyona, 1999). Readers may not attempt to comprehend the information in the graphical device and instead spend that time "not thinking about anything" (Norman & Roberts, 2015, p 49). In addition, GDC requires understanding the structures of graphical devices themselves and the integration of information drawn from the graphical devices with that found in the continuous text (Roberts & Bruger, 2017; Guo et al, 2018). Certain instructional practices potentially negatively impact GDC. For example, teachers may choose to simply identify the presence of graphical devices in text or may decrease their level of explanation as the devices grow in complexity (Coleman et al., 2011). Teachers may base their instructional decisions on the erroneous inculcation method, in which learning to decode words within a non-fiction text is believed to provide sufficient skills to understand the more complex structures within that text (Madden et al., 2014).

1.3. T/E DBL: Context for GDC

The 2019 NAEP Reading Framework states "the situation for reading often determines the way that readers prepare for and approach their task" (National Center for Education Statistics, US Department of Education, 2019, p. 3), demonstrating the importance of authentic contexts in reading comprehension. However, there remains a paucity of research addressing GDC pedagogies where readers are specifically encouraged to explore the content in context as a strategy for promoting their comprehension of nonfiction text (Schugar & Dreher, 2017). Those few prior studies investigating reading comprehension supported through authentic tasks and practices only addressed authentic science tasks (Romance & Vitale, 2005; Guthrie et al., 2006). More importantly, all were focused on nonfiction reading comprehension as a whole, not on GDC specifically.

Promoting GDC within authentic contexts necessitates an understanding of how graphical devices are used in those disciplines where they are an integral component of disciplinary practices. One such discipline is engineering whose practices are "best communicated through sketches, diagrams, graphs, models, and products" (National Research Council, 2012, p.74). Emphasis on both GDC and engineering through the design of technological solutions increases at the upper elementary level, presenting engineering as an authentic context for GDC where T/E DBL is employed as the pedagogical approach. T/E DBL utilizes open-ended design challenges to intentionally impose a genuine need to explore concepts inherent to the design of a viable solution and immerses them in the content and practices of the engineering disciplines (Hmelo et al., 2000; Wells, 2016b; Wells, 2021; Wells & Van de Velde, 2020) where understanding and using graphical devices is an inherently required skill. As such, T/E DBL provides the opportunity for teaching GDC within a truly authentic context. To address the gap in the research on this method, this study examined the relationships between GDC and student engagement in T/E DBL engineering challenges as an integral part of fifth grade reading instruction. The research question guiding this study asked: What relationship exists between design-based learning challenges which are supported by discipline-specific graphical devices and students' (a) frequency of use of discipline-specific graphical devices, (b) comprehension of science and engineering discipline-specific graphical devices in texts which are used to support the design-based learning challenge, and (c) comprehension of science and engineering discipline-specific graphical devices in novel texts?

Figure 1.
Research Implementation Schedule



2. METHOD

The research design employed for this study followed a mixed method exploratory embedded, multiple case study approach, wherein qualitative data collected from a variety of instruments were used to assess a participant's prior knowledge, general GDC levels, and resultant reading comprehension of both familiar and unfamiliar texts. Participants were a stratified purposeful sampling of fifth grade students examined as both whole group and reading level dyads (below grade level [BGL], on grade level [OGL], above grade level [AGL]) during their progression through three T/E DBL challenges. Each design challenge was specifically developed to support instruction of elementary students in their use of graphical devices, and lead to improved overall reading comprehension.

2.1. T/E DBL Implementation

This study was conducted over a period of five weeks, consisting of a 1-week pretreatment period, three 1-week treatment cycles, and a 1-week post-treatment period (Fig. 1).

2.2. Measures

2.2.1. Graphical Device Comprehension Assessment (GDCA)

The Graphical Device Comprehension Assessment (GDCA) is an instrument created by Roberts, Norman, and Cocco (2015) to assess GDC. The GDCA generates a profile of a reader's comprehension of seven common graphical devices. During GDCA administration participants are asked to name and explain the graphical devices to create a scaled score for each graphical device that are averaged to determine an average scaled score. The GDCA was used in this study as a means of documenting GDC changes as a result of engagement in T/E DBL. Only questions on tables, surface, and cross-sectional diagrams were selected and modified from the original GDCA to specifically target graphical device categories prevalent in authentic science and engineering content and practices.

2.2.2. Reading Comprehension Assessment

The reading comprehension assessment rubric used in this study is a modified version of the one developed by Taboada et al. in 2009. Reading comprehension was assessed by having participants read content-specific passages and then generate written responses to an open-ended prompt. Responses are evaluated and given a score of 1 to 6 based on a six-level scoring rubric. Three science-focused passages and three engineering-focused passages were developed to target specific science and engineering concepts (Table 2) inherent to the design challenges that aligned with standards listed in the Standards for Technological and Engineering (ITEEA, 2000, 2020) and in Virginia's Science Standards of Learning.

Table 2.
Alignment of Standards-Based Concepts for Reading Comprehension Assessment Passages

Passage Topic	Concepts Targeted in Applicable Standard
Technological Systems	STEL-2M Differentiate between inputs, processes, outputs, and feedbacks in technological systems (ITEEA, 2020)

Greenhouse Design	STEL-2I Describe the properties of different materials (ITEEA, 2020)
Biomimicry	STEL 2J Demonstrate how tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing (ITEEA, 2020)
Types of Roots	4.2 The student will investigate and understand that plants and animals have structures that distinguish them from one another and play vital roles in their ability to survive. Key ideas include b) plants and animals have different structures and processes for obtaining energy (VA DOE, 2018a)
Greenhouse Effect	5.6 The student will investigate and understand that visible light has certain characteristics and behaves in predictable ways. Key ideas include a) visible light is radiant energy that moves in transverse waves; b) the visible spectrum includes light with different wavelengths; c) matter influences the path of light; and d) radiant energy can be transformed into thermal, mechanical, and electrical energy (VA DOE, 2018b)
Flowers & Pollination	4.2 The student will investigate and understand that plants and animals have structures that distinguish them from one another and play vital roles in their ability to survive. Key ideas include c) plants and animals have different structures and processes for creating offspring (VA DOE, 2018a)

Passages about the targeted science and engineering concepts that included graphical devices were drawn from grade-level appropriate trade books, textbooks, instructional passages, and informational websites. Passages were used with only slight modifications made when necessary to maintain alignment with the research design. Six separate six-level rubrics were developed using similar language and classification requirements to those in the 2009 Taboada et al. study rubrics to maintain item validity. As the rubric score increased in level, the complexity of use of graphical devices also increased.

2.2.3. Design Challenges

Provided as the T/E DBL context for the study, participants participated in a series of three Design No Make (DNM) challenges, each created with graphical devices embedded in the reading passages containing information critical to designing a solution. The three DNM challenges addressed the topics of irrigation, plant packaging, and pollination respectively, and contained detailed criteria written intentionally to necessitate the use of the embedded graphical devices. As a DNM, participants were asked to sketch and explain a design without building a prototype. Post-design challenge questions were included to guide participants towards use of the reading passages and to provide a uniform approach for post-design challenge discussions. All design challenge sessions were audio/video recorded for later analysis.

2.2.4. Frequency Observation Instrument

The Frequency Observation Instrument (Fig. 2) was a rubric developed to monitor the frequency of participant references to graphical devices embedded in passages read during a design challenge. The design criteria in each T/E DBL challenge were written to deliberately require information found only in a graphical device. As a result, all participant references to passages read during the T/E DBL challenge were specifically to an embedded graphical device.

Figure 2.
Frequency Observation Rubric

Observation Period	Behaviour Descriptors	Tallies	Time Stamps
Initial Design Phase			
	student looks at passages with no oral discussion (including self-talk) or dyad interaction		
	student initiates interaction with passages by referencing information orally (including self-talk) while looking at passages		
	student initiates interaction with passages by pointing to passages with or without oral communication		
	student interacts with passages in response to partner's verbal or nonverbal reference to the passages		
	student interacts with passages in response to researcher's questioning or prompts		
Iteration Phase			
	student looks at passages with no oral discussion or dyad interaction		
	student initiates interaction with passages by referencing information orally while looking at passages		
	student initiates interaction with passages by pointing to passages with or without oral communication		
	student interacts with passages in response to partner's verbal or nonverbal reference to the passages		
	student interacts with passages in response to researcher's questioning or prompts		

The rubric for recording observation frequencies also denoted the type of text interaction and if the interaction occurred during the initial design or iteration phase.

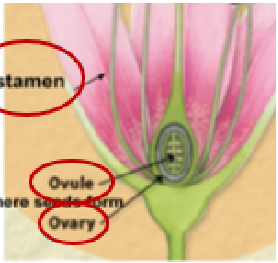
3.2.6 Content Analysis of Participant Design Challenge Responses

The frequency of passage interaction indicates how often the interaction occurs but does not specify what graphical device information is actually being used by the participant. Content analysis of participant responses was conducted to indicate the type(s) of interaction specific to the graphical device. Any words or phrases used in the graphical devices embedded in the design challenge reading passages that were not used anywhere in the continuous text of the passages were identified as "unique". Participant responses (Fig. 3) were then analysed for instances where these unique words and phrases were used.

Figure 3.
Examples: Student Responses Demonstrating Categories of Graphical Device Usage

<table>
<tr><th>Graphical Device</th><th>Participant Response</th></tr>
<tr><td>

Challenge: Flowers and Pollination



</td><td>

Category: Exact Quote

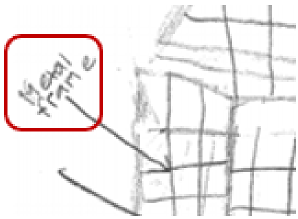
</td></tr>
<tr><td>

Challenge: Designing a Greenhouse

<table>
<tr><th colspan="3">Greenhouse Building Materials</th></tr>
<tr><th>Part of greenhouse</th><th>Material it is made out of</th><th>Part's job</th></tr>
<tr><td>Covering</td><td>Clear plastic or glass</td><td>to let sunlight through</td></tr>
<tr><td>Frame</td><td>Metal, wood, hard plastic</td><td>to hold up the covering and withstand wind</td></tr>
<tr><td>Floor</td><td>Soil, wood, brick, stone, plastic</td><td>to hold on to heat from the sun and protect from the cold of the ground</td></tr>
</table>

</td><td>

Category: Excerpt



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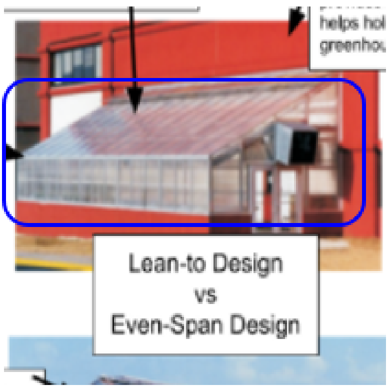
Challenge: Designing a Greenhouse



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Category: Image

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3. RESULTS

Pre and Post intervention administration of the GDCA instrument provided data comparisons (Table 3) regarding the participants' comprehension of the purposes of graphical devices as well as their comprehension of the information contained within those devices.

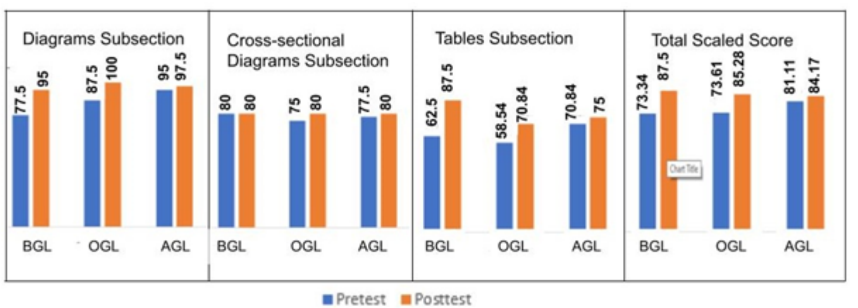
Table 3.
Comparison of Pre/Post-test GDCA Scores for Total Participants

GDCA Subsection	M	n	SD	SEM	df	*t*	p	ES
Diagrams								
Pre-test	86.67	6	11.69	1.71	5	3.08	0.027*	1.26
Post-test	97.50	6	4.18	4.77				
Cross-sectional Diagrams								
Pre-test	77.50	6	5.24	1.67	5	2.08	0.093 a	0.85
Post-test	81.67	6	4.08	2.14				
Tables								
Pre-test	63.89	6	12.55	4.12	5	2.50	0.055 a	1.02
Post-test	77.78	6	10.09	5.12				
Scaled Score								
Pre-test	76.02	6	6.32	2.58	5	3.46	0.018*	1.41
Post-test	85.65	6	1.77	0.72				

Note. *p <.05, two-tailed, paired, a = H_0 cannot be rejected with an α of 0.05

To determine statistically significant differences between pre and post-tests, mean scores of the total population for each subsection of the GDCA were analysed using a paired *t*-test with an alpha of 0.05. Similarly, mean scaled scores were analysed for statistical significance of the GDCA as a whole. Analyses indicate significance for the Diagrams subsection and for the Scaled Scores. It is of note that the Tables Subsection was approaching significance. Given the low number of participants in each reading level, the comparison of dyad pre/post GDCA data was conducted (Fig. 4) to simply identify any patterns and/or information not accurately reflected in the statistical analyses.

Figure 4.
Subsection Score Pre/Post Comparisons by Reading Level Dyad



Note. BGL – below grade level; OGL – on grade level; AGL = above grade level

Analyses reveal overall higher post scores across all dyads, with the greatest impact on GDC seen in the Diagrams and Tables subsections, as well as in the Scaled Scores for the BGL and OGL dyads. Interestingly, while the Diagrams pre-test scores for the BGL and AGL dyads had the largest difference (17.5), the post-test difference between these two dyads was only 2. These findings indicate that the general understanding of diagrams between the BGL and AGL dyads equalizes following engagement in T/E DBL. Furthermore, findings demonstrate the greatest impact of T/E DBL engagement is increased understanding of diagrams and tables.

3.1. Reading Comprehension

Reading comprehension was assessed before and after each T/E DBL challenge. As described previously, participants received a score from zero to six that represented their level of comprehension of the text, with scores above 2 denoting the use of graphical devices in the responses. For Design Challenge 1, data in Table 4 show only participants 1 and 5 receiving pre-test scores of 3 reflecting minimal use of graphical devices in their responses, while in Design Challenge 3 only three post-tests' scores indicate graphical devices were not used. These findings demonstrated that by the end of the study for both science and engineering passages, more participants used graphical devices in their responses. In addition, twenty-four out of thirty-six (75%) of the reported scores increased from the pre-test to the post-test.

Table 4.
Participant Pre/Post Reading Comprehension Score per Design Challenge

Participant	Passage	Design Challenge 1		Design Challenge 2		Design Challenge 3	
		pre	post	pre	post	pre	post
P1: BGL							
	Science	3	3	1	4	3	4
	Engineering	2	2	3	3	3	4
P2: BGL							
	Science	1	1	1	4	2	2
	Engineering	0	1	2	3	1	2
P3: OGL							
	Science	2	2	2	2	4	4
	Engineering	2	1	1	2	2	3
P4: OGL							
	Science	2	2	1	2	3	3
	Engineering	2	2	1	2	2	2
P5: AGL							
	Science	3	4	2	4	3	3
	Engineering	2	2	3	5	3	3
P6: AGL							
	Science	2	2	2	2	3	3
	Engineering	2	2	3	2	3	3

Note. BGL = below grade level; OGL = on-grade level; AGL = Above grade level 0 = no understanding, 1 = basic understanding of facts-simple, 2 = basic understanding of facts-extended, 3 = conceptual understanding of concepts-simple, 4 = conceptual understanding of concepts-extended, 5 = misunderstanding of relationships-simple, 6 = understanding of relationships–extended

3.2. Pre-test Comparisons

Since the Reading Comprehension Assessment pre-tests were unfamiliar to the participants, the pre-test scores can be used to determine how participants comprehend novel (unfamiliar) texts. Participants' comprehension of novel science and engineering texts which include graphical devices was evaluated by comparing participants' comprehension assessment pre-test scores across the three design challenges. The pre-test scores for the engineering passages were analysed for statistical significance using a one-way repeated ANOVA with the design challenge (Design Challenge 1, Design Challenge 2, Design Challenge 3) as the independent variable and pre-test scores as the dependent variable. The same method was used for the pre-test scores for the science passages. Within subject ANOVA results indicate no significant increase in pre-test scores between design challenges $F(2, 10) = 1.86$, $p = <0.206$ partial $\eta^2 = 0.27$ for the engineering texts, demonstrating that participants did not significantly improve their comprehension of novel engineering texts from the beginning of the first design challenge to the third. A second one-way repeated ANOVA was run with the design challenge (Design Challenge 1, Design Challenge 2, Design Challenge 3) as the independent variable and the science reading comprehension pre-test scores as the dependent variable. Within subject ANOVA results indicate a significant increase in pre-test scores between design challenges $F(2, 10) = 13.26$, $p =<0.002$, partial $\eta^2 = 0.73$ and demonstrating that participants' comprehension of novel science texts did increase significantly from the beginning of the first design challenge to the third. The post hoc test results shown in Table 5 revealed that participants' science reading comprehension pre-test scores did significantly increase from Design Challenge 2 (M= 1.50) and Design Challenge 3 (M= 3.00), demonstrating that participants' comprehension of novel science texts significantly increased between those two design challenges.

Table 5.
Comparisons: Science Pretest Post Hoc (n=6)

Design Challenge	M	Design Challenge	M	MD	SE	*p*
Challenge 3	3.00	Challenge 1	1.67	0.83	0.31	0.127
Challenge 3	3.00	Challenge 2	1.50	1.50	0.25	0.003*
Challenge 2	1.50	Challenge 1	1.67	-0.67	0.33	0.306

Note. MD = mean difference; SE = standard error, *p<.01

3.3. Frequency Observation Rubric

The Frequency Observation Rubric tracked all interactions of participants with the provided science and engineering texts during the design challenges. Results presented in Table 6 show participant interactions with the passages not only equalized across reading levels, but increased from Design Challenge 1 to Design Challenge 3 for all participants.

Table 6.
Participant Total Text Interactions

Participant	**Frequency of text interactions**		
	Design Challenge 1	Design Challenge 2	Design Challenge 3
P 1 BGL	2	1	35
P 2 BGL	3	3	28
P 3 OGL	1	0	22
P 4 OGL	0	1	18
P 5 AGL	13	10	30
P 6 AGL	9	11	31

Note. P = participant; BGL = below grade level; OGL – on-grade level; AGL = Above grade level

To determine if this increase was statistically significant, a one way repeated ANOVA was run with the design challenge as the independent variables and the total frequency counts as the dependent variable. Results of the within subject ANOVA indicate that there was a significant difference in frequency counts between design challenges $F(2, 10) = 85.80$, $p =<0.001$, partial $\eta^2 = 0.95$. Participants interacted with the passages significantly more by the last design challenge. Post hoc test results (Table 7) revealed the frequency of text interactions significantly increased from Design Challenge 1 (M= 4.67) to Design Challenge 3 (M= 27.33) and also significantly increased between Design Challenge 2 (M = 4.33) and Design Challenge 3.

Table 7.
Frequency of Text Interaction: Post Hoc Comparisons

Design Challenge	**M**	**Design Challenge**	**M**	**MD**	**SE**	**p**
Design Challenge 1	4.67	Design Challenge 2	4.33	0.33	.72	1.000
Design Challenge 1	4.67	Design Challenge 3	27.33	22.67	2.38	.000642*
Design Challenges 2	4.33	Design Challenge 3	27.33	23.00	2.45	.000693*

Note. MD = mean difference; SE = standard error; *p<.01

3.4. Content analysis

Content analysis of student responses to the design challenges was used to identify unique words or phrases that had been drawn from either the diagram or table within the texts (Table 8).

Table 8.
Instances of Information Drawn from Graphical Devices

Reading Level	**Design Challenge 1 GD Information**		**Design Challenge 2 GD Information**		**Design Challenge 3 GD Information**	
	Tables	Diagrams	Tables	Diagrams	Tables	Diagrams
BGL	0	0	0	0	0	4
OGL	0	0	1	0	0	3
AGL	0	0	2	1	0	4

Note. GD = Graphical Device; BGL = below grade level; OGL = on-grade level; AGL = Above grade level

Results indicate the use of unique words and phrases taken from graphical devices increased across design challenges and an increased use not only by the above-grade dyad, but by dyads at all levels. This increased use of content from graphical devices by all participants demonstrates they interacted with the graphical devices more frequently as the study progressed.

4. CONCLUSIONS

The impetus for this research was the continued weak performance of U.S. elementary students on national assessments of reading comprehension. Such weak performances suggest a need for disciplinary-specific literacy instructional strategies that more effectively promotes student reading comprehension in general. More importantly, strategies that promote comprehension of nonfiction/informational text inclusive of graphical devices containing essential disciplinary information.

Results from this case study clearly demonstrate the potential of T/E DBL for developing design thinking in learners at the elementary level which transfers to other disciplines. The pedagogical approach used in T/E DBL provides elementary educators with instructional strategies that uniquely prepare young learners to recognize, comprehend, and use disciplinary information contained within graphical devices. Learners prepared to utilize a designerly way of coming to know possess the capacity to transfer that knowledge acquisition heuristic (Wells, 2021, p. 235) for interpreting information presented in discipline-specific text inclusive of graphical devices, and which leads to their better understanding of the concepts within that text.

Prior research has recognized that GDC instruction is impacted by the erroneous assumption that teaching students to read continuous text will prepare them to read and understand graphical devices. The unique challenges of GDC will require pedagogical approaches that address those challenges. T/E DBL curricula provide a specific, immediate need and payoff for students using and understanding graphical devices. Findings from this research imply that readers, particularly those who read below grade level, will benefit from GDC instruction through T/E DBL design challenges because they are consistently reinforced in the benefit of using graphical devices by improved designs. Based on findings from this research, one major implication is that elementary reading instruction must acknowledge GDC as a separate process from reading comprehension of nonfiction continuous text and must shift their pedagogy accordingly. Furthermore, this study demonstrates that T/E DBL is a viable pedagogical approach for teaching GDC at the elementary level.

Additionally, providing training to elementary educators on GDC and the role GDC plays in authentic contexts such as science and engineering may be necessary to support the creation and implementation of T/E DBL curricula that effectively support GDC. Just as reading comprehension of continuous text does not automatically transfer to GDC, training focused on teaching decoding and comprehension of continuous text may not automatically transfer to teaching GDC. Teacher preparation and professional development programs must address this need moving forward.

Given this research presents results from a small case study, needed is a larger study employing T/E DBL as an instructional strategy used to promote GDC in elementary level learners. As well, further research is needed investigating those unique technological/engineering design-based learning teaching strategies shown to prepare students with the capacity for design thinking necessary for exploring, comprehending, and understanding information encountered in authentic contexts. Such research will help establish T/E DBL as an integral teaching strategy at the elementary level for better preparing learners as both problem solvers and critical thinkers.

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A New Framework of Technology and Engineering Education Proposed by the Japan Society of Technology Education

Jun MORIYAMA, Hyogo University of Teacher Education, junmori@hyogo-u.ac.jp
Toshikazu YAMAMOTO, Saitama University, tyamamot@mail.saitama-u.ac.jp
Hiroyuki MURAMATSU, Shinshu University, muramatu@shinshu-u.ac.jp
Hirotsugu TAGUCHI, Kumamoto University, taguchi@educ.kumamoto-u.ac.jp
Tadashi OHTANI, Tokyo Gakugei University, t-ohtani@u-gakugei.ac.jp
Ping YANG, Kumamoto University, yangping@educ.kumamoto-u.ac.jp
Akira KIKUCHI, Naruto University of Education, kikuchi@naruto-u.ac.jp
Koushi UENO, Hakuoh University, k-ueno@fc.hakuoh.ac.jp
Yoichi MIYAGAWA, Iwate University, miyagawa@iwate-u.ac.jp
Shigekazu WATANABE, National Institute for Educational Policy Research, s-watanabe@nier.go.jp

ABSTRACT

In this paper, a new framework for technology and engineering education which was proposed by the Japan Society of Technology Education (JSTE) was introduced. We conducted a survey on Japanese junior high school students about status of "Technology" learning. As a result, it was indicated that Japanese students have a positive perception of "Technology" classes, however, there is a lack of learning activities related exploring technology, and design problem-solving is not adequately linked to the abilities for technological innovation and governance. From this, we developed a new framework focused on enhancing exploratory activities and problem-solving related to engineering. The proposal includes the Triple-Loop Model as engineering design process, the connections between physical and cyber technologies in that scope., and the learning model of STEAM education that centred engineering design process with various connections among all subject area.

Keywords: The Japan Society of Technology Education, Technology and Engineering Education, Proposal of new framework, Japan

1. INTRODUCTION

As STEM/STEAM (Science, Technology, Engineering, Mathematics, /and Arts) education flourishes worldwide, the importance of technology and engineering education is increasing. The International Technology and Engineering Educators Association (ITEEA) states in the Standards for Technology and Engineering Literacy (STEL) as "Extensive changes have taken place in education in the past twenty years. There is an increased emphasis on design, and specifically on technology and engineering design, in the PreK-12 curriculum"(ITEEA 2020). However, the role of technology and engineering education in STEM/STEAM education is sometimes underestimated. In the STEL, it is also mentioned, "In spite of this recognition, the role that technology and engineering play, and should play, in the education of PreK-12 students is often narrowly defined and misunderstood." In such a situation, it is important to clearly define the role of technology and engineering education in STEM/STEAM education at an early stage for educational reform. This is one of the big reasons for the publication of STEL by ITEEA.

In the case of Japan, since 2019, there has been an increasing focus on STEAM education within the Ministry of Education, Culture, Sports, Science and Technology (MEXT). In particular, MEXT is paying attention to the characteristics of STEAM education as transdisciplinary learning that integrates STEM and Arts (MEXT 2019). It is highly likely that STEAM education will become an important concept in the revision of the next national curriculum in Japan. However, the approach of educational reform in Japan are unique, and there is a need to seamlessly connect the history of previous educational reforms with new concepts such as STEAM education. Therefore, it may be difficult to apply the ITEEA‘s STEL directly to Japan. It is likely that other countries with their own national curricula may face similar difficulties. Therefore, in the context of Japan, it is necessary to have academic proposals that play a similar role to ITEEA's STEL in order to clarify the role of technology and engineering education in STEAM education.

For these reasons, the Japan Society of Technology Education (JSTE) initiated a project to develop a new framework for technology and engineering education in Japan. JSTE is an academic society that lead researches in technology education in Japan. JSTE has already published "Technology Education in the 21st Century" (first edition) in 1999, followed by a revised edition in 2012, and illustrative examples of contents in 2014 as frameworks for technology education in Japan (JSTE 1999, 2012, 2014). These documents proposed the principles, objectives, contents, and problem-solving process of technology education in Japan.

On the other hand, the revision of the national curriculum is deliberated upon by relevant subcommittees of the Central Council for Education (CCE) of the MEXT, in response to consultations from the Minister of MEXT. For each subject area, specialised committees in the CCE consisting of university researchers, prefectural educational supervisors, school teachers, and other representatives are involved in the deliberations. Usually, academic societies are not directly involved in this process. However, in case of technology education, the proposal by JSTE such as "Technology Education in the 21st Century" (1999, 2012), have had a certain level of influence on the revision of the national curriculum. UENO (2023) pointed out that during the revisions of the curriculum in 2008 and 2017, the president and vice-president of JSTE became members of the specialised committees. This inclusion facilitated the implementation of curriculum reforms based on the ideas presented in "Technology Education in the 21st Century." Currently, discussions have begun in Japan regarding the revision of the next educational reform. It is expected that JSTE will continue to have a certain level of influence on this educational reform, similar to previous revisions.

In fact, it has been more than 20 years since the first edition of “Technology Education in the 21st Century” that was published in 1999, and during this time there have been significant changes in society and technology. Especially, in recent years, there has been increasing emphasis on the Fourth Industrial Revolution, Connected Industries, highlighting the integration of new technologies such as AI, IoT, robotics, Big Data processing and so on with traditional industries such as agriculture, manufacturing, and so on. In Japan, this type of new society is called as Society 5.0. Society 5.0 refers to a concept that the Japanese government aims to achieve, which represents a new type of society. Society 1.0 represents the hunting society, 2.0 represents the agricultural society, 3.0 represents the industrial society, and 4.0 represents the information society. Society 5.0 envisions a society where Society 1.0 to 3.0 are highly integrated with Society 4.0, aiming for sustainable development and the resolution of social challenges. In order to actualize society 5.0, it is important to connect and integrate of cyber technologies and physical technologies. This requires for a highly integrated approach between these new technologies and existing industries. These changes in society have necessitated a reform of education.

In response to these changes, JSTE has undertaken a revision of "Technology Education in the 21st Century" and has developed "The New Framework of Technology and Engineering Education for Creating a Next Generation Learning." In this paper, we introduce the details of this project. The authors were key members of this project in JSTE.

94 CURRENT STATUS OF TECHNOLOGY EDUCATION IN JAPAN

94.1 Objectives and Contents of Current Technology Education in Japan (Revised in 2017)

First, we introduce the current status of technology education in Japan, which was revised in the 2017 national curriculum (MEXT 2017). Technology education as general education in Japan, is positioned within the subject "Technology" as part of the subject area of "Technology and Home Economics" in junior high school curriculum. In elementary school curriculum, some learning activities include hands-on activities for making things and computer programming activities in various subject areas. However, these activities are not systematised as technology education. In high school, there is a subject called "Informatics," but there are no other subjects that specifically deal with other areas of technology. Here, let's focus on the junior high school subject "Technology." The number of lessons of “Technology” allocated for each grade level are 35 lessons per year (1 class is 50 minutes) in 7th grade (13 years old), 35 lessons per year in 8th grade (14 years old), 17.5 lessons per year in 9th grade (15 years old). In the revised national curriculum of 2017, the objectives of “Technology” are as follows:

94.1.1 Objectives:

(i) Fostering abilities that contribute to the creation of a better life and sustainable society through practical and experiential activities related to technology, utilizing a view-point and way of thinking of technology.

(ii) (1) To develop foundational understanding of material processing, biological cultivation, energy conversion, and information technologies that are utilized in daily life and society, to acquire skills related to these technologies, and to gain deeper understanding of relationship between technologies and daily-life, society, and the environment.

(iii) (2) To develop technological problem-solving abilities such as to identify problems related to technology within daily life and society, set one's own task, finding solution, expressing through drawing or other forms, producing (or cultivating), and evaluating and improving.

(iv) (3) To cultivate practical attitudes for appropriate and honest pursuit of technological devices and innovations to realise a better life and build a sustainable society.

Also, the learning contents of "Technology" can be summarized as shown in Table 1 (this summary is edited by the authors.).

Table 1.
Overview of Learning Contents of "Technology" in Japan (Revised in 2017)

		Content A Material and Processing Technology	Content B Biological Technology	Content C Energy Conversion Technology	Content D Information Technology
1	(1)	Understanding the principles and mechanisms of technologies that supporting our daily life and society			
	(2)	Reading ingenuity of technological problem-solving that embedded in existing products or systems.			
2	(1)	Skills for fabrication, production, and cultivation.			
	(2)	Identifying problems, setting tasks, designing solutions and executing techmological problem-solving.			
3	(1)	Understanding the concepts of technology and the role of it in development of society.			
	(2)	Thinking of Evaluating, selecting, managing, operating, improving, and applying technology, and cultivating creative attitude for actualization of sustainable development of society.			

Note: In Content D, section 2(1)(2) in other contents are divided into 2(1)(2)"problem solving by programming with network technology" and 3(1)(2) "problem solving by programming with sensing and control technology". Therefore, 3(1) (2) in other contents is become 4(1)(2) in Content D.

The goal of this learning in "Technology" is for students to acquire the ability to evaluate, select, manage, operate, improve, and apply technology, fostering their creativity and problem-solving skills. Among these, "ability to evaluate, select, manage, and operate technology" refers to the ability of technological governance, which is multidimensional evaluation of benefits and risks of technology in society and democratic controlling of technological development for future. Also, the "ability to improve and apply technology" represents the ability of technological innovation, which means creation of new value in society by using technology. In this curriculum, especially, the construction of 4 learning contents and the concept of abilities for technological innovation and governance were influenced by JSTE's "Technology Education for the 21st Century" (2012 edition).

94.2 Survey on actual status of students' awareness for learning "Technology"

We conducted a survey on the learning situation of "Technology" among Japanese junior high school students (MORIYAMA et.al 2018). The subject was 1,656 7th to 9th grade students in Hyogo Prefecture, Japan. The questionnaire consisted of four items to assess their awareness and experiences regarding "Technology" classes. First, students' awareness towards "Technology" learning is shown in Table 2. Table 2 indicate that students have a positive awareness of the importance of "Technology" classes and perceive them as enjoyable and understandable. Also, it is suggested that students have interest in technologies that support our daily lives and society. The status of learning activities related to problem-solving is shown in Table 3. It is suggested that students are actively engaged in self-directed and interactive learning in "Technology" classes. However, there is a slight weakness in awareness of linking their learning experiences to social issues. The status of students' problem-solving experiences is shown in Table 4. From Table 4, it was indicated that students are engaged in problem-solving activities such as project management, planning and design, and troubleshooting in "Technology" classes. However, it was found that students are not sufficiently engaged in exploratory activities such as inquiry, experimentation, and observation related to technology.

Table 2.
Students' awareness towards "Technology" learning

Items	*Mean*	*SD*
Importance of learning technology.	3.24	0.70
Joy of learning technology	3.35	0.66
Understanding of technology learning	3.08	0.71
Interest in technologies that support our daily life and society	3.05	0.69

N = 1656
4 point scale

Table 3.
Status of learning activities related problem-solving

Items	*Mean*	*SD*
Active attitude for learning in technology classes	3.12	0.70
Collaborative learning in technology classes	3.25	0.72
To link own learning experiences with social issues	2.34	1.49

N = 1656
4 point scale

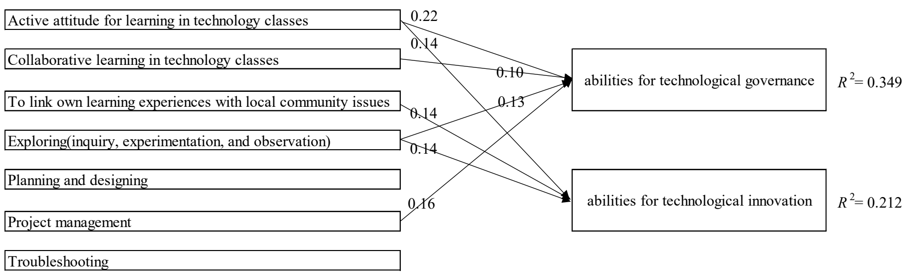
Table 4.
Status of students' problem-solving experiences

Items	*Mean*	*SD*
Exploring(inquiry, experimentation, and observation)	2.64	0.89
Planning and designing	3.18	1.34
Project management	3.22	0.67
Troubleshooting	3.18	1.34

N = 1656
4 point scale

A multiple regression analysis was conducted to examine the impact of these learning activities on students' abilities for technological innovation and governance (Figure 1). Incidentally, Multiple Regression Analysis is a statistical method used to investigate how multiple independent variables (predictors) collectively influence a single dependent variable (outcome). By using Multiple Regression Analysis, we can quantify and assess the causal relationships between several predictor variables and a target variable. As a result, unfortunately, overall, the influences of learning activities to the abilities for technological innovation and governance were weak. Also, the results suggest that problem-solving activities related to planning and design, as well as troubleshooting, are not any contributing to develop the students' abilities. It is considered that this is due to the limited design activities, which may be restricted to activities such as selecting and improving models prepared by the teacher.

Figure 1.
Causal relationship toward students' abilities for technological innovation and governance



Based on these results, the following points can be noted regarding the actual status of students in "Technology" classes in Japan. That is, Japanese students have positive perception of "Technology" classes, however, there is a lack of sufficient learning activities that involve exploring technology, and the most important element of technology education, which is design problem-solving, is not adequately linked to the development abilities for technological innovation and governance. From this point of view, it is believed that the future of technology education in Japan should focus on enhancing exploratory activities and problem-solving related to engineering. Considering the role of STEM/STEAM education moving forward, it is necessary to prioritize design learning as the core and foster the abilities for technological innovation and governance.

95 "TECHNOLOGY EDUCATION IN THE 21ST CENTURY" PROJECT

In light of this, JSTE initiated a project to revise the "Technology Education in the 21st Century " curriculum in 2017. As part of JSTE's initiatives, we first established a “Technology Education Ideathon” session. "Ideathon" is a term coined by combining "idea" and "marathon," which refers to a creative discussion platform where participants continuously generate various ideas. JSTE has been organising "Ideathon" on an annual basis since 2017. Additionally, the project has held four symposiums during JSTE's annual conferences from 2019 to 2022, in order to gather various opinions from JSTE’s members. In this process, the name of "technology education" was changed to "technology and engineering education". Then, the project reached to publish "the New Framework for Technology and Engineering Education to Create the Next Generation of Learning" (NGTE) in 2021.

95.1 Objective of Technology and Engineering Education in NGTE

NGTE divides technology and engineering education into two categories for discussion: professional education for cultivating technological experts such as engineers, technologists, etc., and general education for fostering technology and engineering literacy among all citizens. And particularly, NGTE focuses on technology and engineering literacy education. NGTE defined that acquiring the abilities for technological innovation and governance is considered as final goal of technology and engineering literacy. An overview of the objectives to achieve this goal are summarised as in Table 5.

Table 5.
Overview of Objectives of Technology and Engineering Education in NGTE

Technology and Engineering Literacy	Competencies enhanced by technology and engineering literacy		
	as individual	Engaging with others	Life and social development
✓Scientific understandings of technology and engineering ✓Understandings of interconnection between technology and society,	Integrative recognition and application abilities in both STEM and Arts	logical communication (expression, share, argument)	Career development and self-actualization
✓Development of abilities to technological problem-solving and engineering.	design thinking critical thinking logical thinking computational thinking system thinking GRIT etc	cooperative skills collaborative skills menbership leadership followership etc	Abilities to move various projects forward in lifelong
✓Development of abilities to participate in technological governance in society.	Jadgment abilities Decision making abilities Fairness Citizenship etc	Abilities to engage in democratic and constructive dialogue	
✓Development of abilities to participate in technological innovation in society.	Creativity Proposal skills etc	Open mind Reciprocal relations etc	Abilities for building democratic and sustainable societies

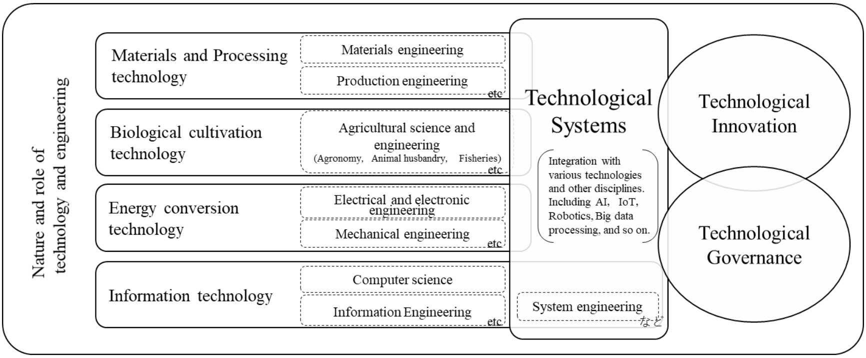
In Table 5, technology and engineering literacy is positioned on the left side. It shows how this literacy enhance generic competences. It indicates that technology and engineering literacy plays an important role not only in developing abilities related to technology and engineering but also in developing generic competences at three layers: as "individual", "engaging with others", and "life and social development." The envisioned future shape of students who have leant technology and engineering education are "A: Technologically literate citizens", "B: Responsible users of technology", "C: Creative individuals as technological problem-solver", "Lifelong learners about technology", "Decision-makers related to technology", "Eggs of engineers", "Promotors of culture to actively support of technological development in society." These images represent the desired outcomes from students in technology and engineering education.

95.2 Scope of Technology and Engineering Education in NGTE

NGTE has strengthened the following two points, considering the content structure of Japan's previous technology education. First, NGTE incorporated elements of engineering science, in order to emphasize problem-solving through the exploration of technology by establishing the relevance between each content and its underlying academic discipline. Secondly, NGTE has enhanced the connections between technology and other diverse areas of expertise to enable students to create new value in a VUCA (Volatile, Uncertain, Complex, Ambiguous) society. This has been incorporated into the learning content as "Technological Systems," emphasizing the interplay between technology and technology, or various other domains in society.

Especially, we addressed the integration of cyber technologies and physical technologies based on the concept of Society 5.0. We thought these contents are linked to the abilities for technological innovation and governance. The proposed scope of technology and engineering education in NGTE is shown in Figure 2.

Figure 2.
Scope of Technology and Engineering Education in NGTE

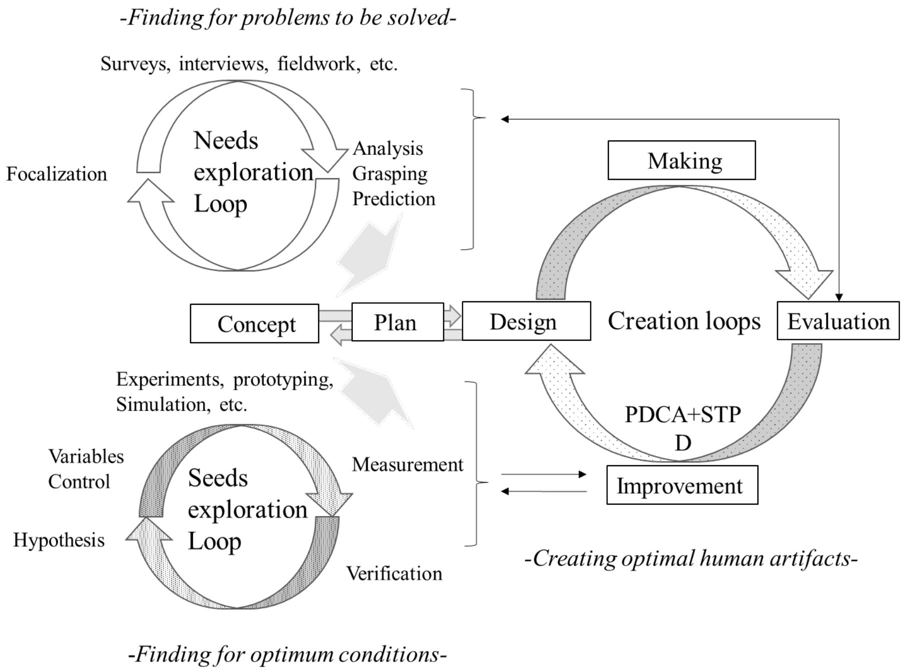


In Figure 2, "understanding of nature and roles of technology" is positioned to cover the whole scope. On of that, individual technology such as "materials and processing technology", "energy conversion technology", "biological cultivation technology", and "information technology" are positioned. Within this construction, engineering science, which is background discipline for each technology, such as materials engineering, electrical and electronic engineering, agriculture science, computer science and so on, is positioned. Furthermore, as content that across individual technology, "Technological Systems" is positioned. This content includes AI, IoT, Robotics, Big Data processing, and more, aims to integrate between cyber and physical technologies. And we aim to connect these learning to technological innovation and governance in order to foster the ability to create new value through technology and enable democratic steering in direction of technology development.

95.3 Triple-loop model of Engineering Design Process in NGTE

As the results of the above survey have shown, there were issues regarding Japanese students did not have sufficient learning experiences to explore principles and mechanisms of technologies, and they could not apply design process to their technological innovation and governance. To address these issues, we proposed the Triple Loop Model of Engineering Design Process. This is shown in Figure 3. The Triple Loop Model illustrated an engineering design process that is constructed from iterative interaction of three loops such as Needs Exploration Loop, Seeds Exploration Loop, and Creation Loop. In the Needs Exploration Loop, students will utilize various methods such as survey, interviews, or fieldwork and analyse various materials and data in order to identify problems, set tasks, and clarify user's needs. In the Seeds Exploration Loop, students set variables and explore optimal conditions for technological problem-solving. Furthermore, students engage in activities such as prototyping and simulations to devise optimal designs. In the Creation Loop, students match both needs and seeds, and they design what should be created by optimisation thinking, and make appropriate products or systems.

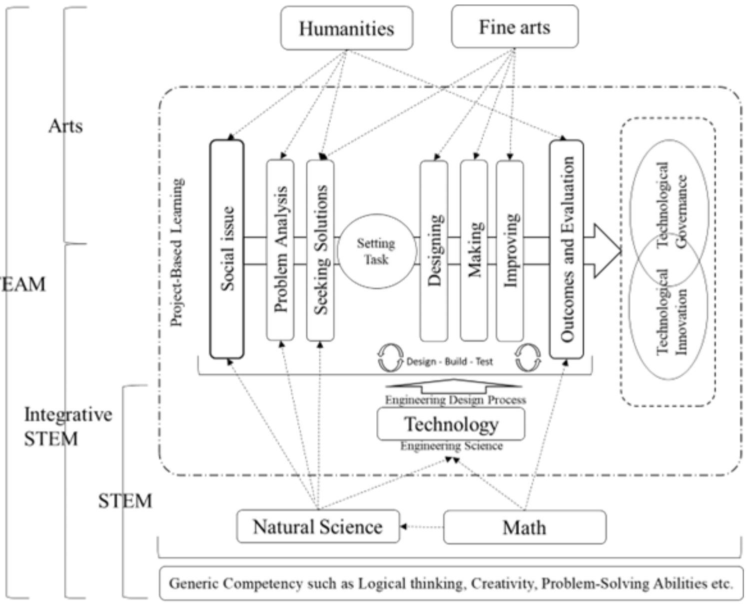
Figure 3.
The Triple Loop Model of engineering design process in NGTE



95.4 A Learning Model of STEAM Education in NGTE

Essentially, technology and engineering play an important role in bridging between natural science and society/culture through design process. Therefore, in the context of STEAM education, technology and engineering literacy has an important role in connecting the disciplines of science, arts, and mathematics. It serves as a link that integrates these disciplines, and makes STEAM education practices more holistic and comprehensive. In general, in STEAM education with Project-based learning, there are opportunities for students to create both technological artifacts and non-technological outcomes. In NGTE, we focused on the former, and have envisioned a practical model of STEAM education that centred engineering-based problem-solving through transdisciplinary learning across all subjects. This learning model can be summarised in Figure 4. This learning model specifically focuses on setting up learning activities for creating technological artifacts such as useful products or systems that may be able to solve authentic problem in our society. Of course, there are various models of STEAM education. This is an example of one that can be implemented in "Technology" classes or "Period of Integrated Study" in Japan's national curriculum.

Figure 4.
Learning Model of STEAM education that centred engineering design process in NGTE



96 CONCLUSION AND FUTURE TASKS

In this paper, we presented an overview of the status of technology education in Japan and introduced the proposed framework for new technology and engineering education by JSTE. As a result, we showed present status of Japanese students as they have a positive perception of "Technology" classes, however, there is a lack of sufficient learning activities that involve exploring technology, and design problem-solving is not adequately linked to the abilities for technological innovation and governance. In the light of these issues in students' learning and changes in society, we developed a new framework that focused on enhancing exploratory activities and problem-solving related to engineering. The proposal included the Triple-Loop Model as engineering design process, the connections between physical and cyber technologies in that scope., and the learning model of STEAM education that centred engineering design process with various connections among all subject area. We intend to use the NGTE to challenge the next educational reform in Japan. We would like to report on the process of this in a future. However, the Scope of Technology and Engineering Education, Triple-Loop Model and STEAM Learning Model are still hypothetical at this stage. It will be necessary to make clear the effects of these strategies through classroom practice.

Finally, as all the documents we introduced in this paper are written in Japanese, we hope that through this paper, the NGTE will be made known to technology and engineering educators in other countries. And we are grateful to members of JSTE who took part in the project for development of the NGTE.

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The Adaptive Subject Pedagogy Model: Understanding Pre-Service Teachers' Pedagogical Reasoning in Design & Technology

David Morrison-Love, University of Glasgow, david.morrison-love@glasgow.ac.uk
Fiona Patrick, University of Glasgow, fiona.patrick@glasgow.ac.uk

ABSTRACT

Here, we share findings from the current phase of a practitioner enquiry project to explore ways of supporting undergraduate technology education ITE (Initial Teacher Education) students to inform their classroom practice with theory, research, and academic knowledge. The practitioner enquiry centres on our work in teacher education with students using a model created by Morrison-Love to scaffold the development of pedagogical reasoning: the Adaptive Subject Pedagogy Model (ASPM) (Morrison-Love & Patrick, 2022). In the first phases of our project, we explored students' challenges in relating theory to practice and developing pedagogical reasoning using focus groups with students and analysis of course assignments. Continued use of the model showed students improving in their connections across knowledges, but many still struggling with the development of coherent evidence informed pedagogical reasoning. Here, we present findings from our analysis of two in-depth interviews we undertook with students to understand more about how they were reasoning through engagement with the ASPM. During the interviews, student submissions were used as a mediating artefact to help scaffold questioning and discussion. The submissions each capture one full cycle of the ASPM for a topic chosen by that student. Use of student submissions in this way provided a tangible focus to help reveal more of the students underlying thinking. We describe the ASPM before reporting on the insights and reflections of two students who have used it to create evidence informed subject pedagogy. We briefly discuss what these findings suggest about thinking with the ASPM and what our evidence suggests more broadly for our own practice as teacher educators.

Keywords: Pedagogical reasoning, Initial teacher education, Adaptive Subject Pedagogy Model, Evidence-Informed Teaching

1. INTRODUCTION

The importance of theory- and research-informed teaching is well understood in the literature (Miles et al., 2016; Evans et al., 2017; Flores, 2018) but is something that many pre-service teachers struggle with during Initial Teacher Education (ITE) and as fully qualified teachers (Flessner, 2012; McGarr et al., 2017). Informing practice with research and theory is increasingly recognised to be a complex and demanding process. It requires that students understand and synthesise forms of knowledge which reside within different learning contexts, systems and structures. In Design & Technology, the demand of using different forms of knowledge to create towards effective classroom practice is two-fold for our ITE students: it is both a feature of technological capability and of pedagogy as the act and art of teaching. Despite our best efforts as Teacher Educators, supporting students to create evidence-informed subject pedagogy remains challenging.

This scholarship project centres on our work with students on a 5-year undergraduate integrated Master's teaching degree (the MDTechEd) in a Scottish teacher education institute where we use the Adaptive Subject Pedagogy Model (ASPM) to scaffold development of evidence-informed pedagogical reasoning (Morrison-Love & Patrick, 2019, 2021, 2022). The model, developed from the work of Shulman (2006, 1987), was a response to challenges students had in their preparation for teaching courses as part of the Design and Technology ITE programme. Students found it difficult to integrate evidence and knowledge from the different parts of their degree programme to inform planning for teaching. They also planned lessons using a behaviourist linear-rationalist approach which begins with learning outcomes before outlining content to be covered and activities to support coverage, ending with a lesson evaluation (John, 2006). As John highlights, this view of planning atomises teaching and learning into 'key elements, which are then sub-divided into tasks, further broken down into behaviours and then assessed by performance criteria' (2006, p.487). The potential richness of teaching and learning is reduced to a 'means-ends approach' (John, 2006, p.487): student teachers see lesson planning in technical terms rather than as something to support the development of pedagogical thinking (Rusznyack & Walton, 2011).

Another issue with our students' planning was the focus on generic rather than subject-specific pedagogies. There was little depth of thinking about the nature of what was to be learned and why, or connection to evidence about what subject-specific pedagogies might best encourage learning. Our concern was that, without this critical reflection, it would be challenging for students to develop the depth and sophistication of pedagogical expertise necessary for teaching Design & Technology.

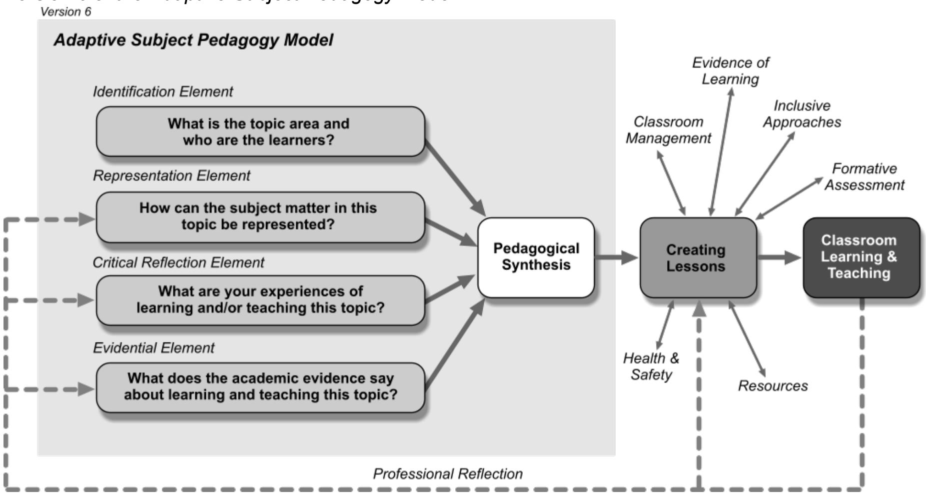
Our evidence so far has shown that the ASPM can help students to improve ideas for subject pedagogy, but some still struggle to connect with evidence and develop their pedagogical reasoning. This paper describes the findings from two interviews in which we asked students to reflect on their own reasoning in a cycle of the ASPM. The research question is: 'What do students' reflections on their use of the ASPM tell us about their pedagogical reasoning?' Our hope is that by understanding this we can develop our own practice as teacher educators to support students more effectively. The following section provides an explanation of the most recent version of the ASPM after which we provide an overview of the methodology.

98 THE ADAPTIVE SUBJECT PEDAGOGY MODEL

The ASPM (Figure 1) is a process-based model that was developed to support ITE students to create evidence-informed pedagogy by integrating research, educational theory and knowledge from across their degree programme. It builds from Shulman's (2006, 1987) ideas of pedagogical content knowledge, pedagogical reasoning and professional knowledge growth. The ASPM comprises four elements and begins with the curriculum. It is not a form of lesson planning and does not frame learning in terms of outcomes. Rather, it develops pedagogical reasoning and the creation of evidence-informed subject pedagogies: the forms of teacher expertise necessary for effective teaching and learning which are often assumed or omitted by rational-behaviourist approaches to planning.

In the more formative stages of using the ASPM, students typically move through each element successively but can use it more flexibly and iteratively as proficiency develops (see Figure 1).

Figure 1
Version 6 of the Adaptive Subject Pedagogy Model



In the identification element, students select a topic area of interest with reference to the curriculum and specify the age/stage of pupils they will work with. For our students, topics have included areas such as 3D modelling, visualisation, practical skills, graphic design, electronics and control systems. It should be noted that the ASPM is not designed to work at the level of individual lessons, and topics must span several lessons over an extended period. From here, students must think through and map out what is important or valuable to learn for their chosen topic and represent this without any reference to pupils or how they might teach it. This will include different concepts, ideas, skills and processes and allows the subject matter of learning to be developed (what we refer to as the subject episteme). Even in cases where knowledge is often thought of as objective, students will still have to interrogate, understand and make decisions about how best to represent and explain it for their educational purposes (e.g. there are several 'correct' ways of defining and representing electrical current).

The identification and representation elements allow students to establish the 'what' of teaching and learning. The critical reflection and evidential elements begin to consider the 'how': the first by eliciting evidence from practice, and the second by eliciting evidence from research. Both forms of evidence seek insight into how the chosen topic could be taught, and some evidence that this approach is effective for learning. In the critical reflection element, students reflect deeply on their own experience as learners and/or teachers of their chosen topic and evaluate how particular approaches have supported understanding (or not). Did particular teaching approaches lead to misconceptions and why might this have happened? Were others particularly effective for developing topic skills or understanding? How do you know? In the evidential element, students identify and analyse published research for evidence of how they might teach their topic effectively. Students are encouraged to include specific reference to subject matter in their search terms to avoid genericism, consider the relevance and applicability of the papers, and avoid seeking evidence that simply backs up an existing idea about how they think something should be taught. It is made clear to students that, for the purposes of pedagogical reasoning, evidence from research is no more or less important than evidence from practice.

In the final stage of the ASPM, students synthesise what they have learned across the elements into a coherent pedagogical proposal for teaching their chosen topic. This is typically written out by students as a teaching approach and requires them to resolve any competing evidence from research and practice. Notably, this reflects something of who they are as developing teachers of Design & Technology.

99 METHODOLOGY

This work is underpinned by a constructivist ontology concerned with exploring the insights and learning of teaching students working to develop pedagogical reasoning through use of the Adaptive Subject Pedagogy Model (ASPM). We employed a purposeful approach to participant selection, inviting students from years 2, 3 and 4 of the MDTechEd programme to participate on a voluntary basis. There were 20 students in each year from a total cohort of 82. Because students were in a dependent relationship with us, they were invited to participate only after all programme assignments had been graded and returned towards the end of the academic year. Our intention was to select the first 2 students to respond from each cohort for the in-depth interview. However, it proved difficult to arrange interviews so two students were interviewed in the first round of data gathering, with a second round of invitations scheduled for the new academic session in September 2023.

Because of the need to focus on concrete, lived examples of working with the ASPM and the passage of time since students submitted their assignments, we used a stimulated-recall method to support students to verbalise their reasoning (Burden et al 2015; Lyle 2013). We developed artefact-mediated semi-structured interviews in which students' own assignment submissions using the ASPM were used to scaffold discussion with us, prompt recall and reduce abstraction by providing a concrete example to refer to. ASPM assignments were linked to specific areas of the Scottish Design and Technology curriculum. We developed the interview protocols and prompts around the different elements of the ASPM and lesson creation process.

The interviews were carried out online using zoom following the recommendations of Gray et al (2020) and recorded with participant consent to support the analysis process. Participating students were sent a summary of the main interview questions and encouraged to reflect on these in advance of the interview. In this early stage of phase 4, one interview was carried out with a student in Year 3 of their programme (Student A, lasting 65 minutes), and one with a student in Year 4 of their programme (Student B, lasting 52 minutes). The recorded interviews were transcribed and analysed using an inductive approach to coding and theme creation (Clarke & Braun, 2017).

100 ETHICAL STATEMENT

Because this research involved summative assignments that we set and assessed, participants were in a dependant relationship. In conducting this research, it was therefore important to maintain our awareness of perceived and real power differentials. Students were made aware that participating or not would have no effect on any existing professional relationships with staff conducting the study, nor would it affect any future assessments. It was made clear that the research was not evaluative of their work, did not seek 'right' or 'wrong' responses, and that they were free to withdraw at any time without the need to provide a reason. This research was approved by the College of Social Sciences ethics committee at the University of Glasgow.

101 FINDINGS

The conversations gave rich insight into the thought processes of the students as they used the ASPM. Student A selected a cycle of the ASPM completed in degree year 2 focused on 'Energy & Efficiency'. Student B selected one focused on 'Cognitive Visualisation' (also completed in Year 2).

101.1 Theme 1: Shifting thinking about planning: from tasks to pedagogies

The conversations supported the idea of linear lesson planning leading to a more technical approach to planning for these students. Student A thought the generic plan was 'tick boxy' and overlong in contrast to the ASPM which enabled a degree of flexibility in approach to create units and then lessons. Student A's thinking shifted from filling in the generic plan with 'tasks' to do in sections of the lesson, to thinking 'how am I going to teach this?' Student B did not engage with the different elements of the ASPM in isolation as might have been the case with the elements of the generic lesson plan. Instead, Student B was aware of the interrelationships between the ASPM elements in their thinking.

For both students, completing a generic lesson plan was a requirement of placement – all ITE programmes in our TEI use a similar plan. However, both noted that the process of completing a cycle of the ASPM was more important to their thinking than writing the generic lesson plan itself. Student A used the ASPM independent of the plan to create topics for use in schools as a student and intended to continue this as a qualified teacher. In developing topics, both students focused on areas of the curriculum they needed to understand more fully, or areas they were challenged by or had difficulty teaching. Student B saw it as a means of enhancing knowledge in relation to classroom difficulties and Student A wanted to continue to evolve the topics after teaching in order to refine them. In this way, both seemed to shift to the more developmental approach to planning that Rusznyack & Walton discuss as a move from creating lesson plans focused on 'descriptions of classroom procedures' to ones that build from 'consideration of how to enable learning' (2011, p.280).

101.2 Theme 2: It takes time: learning to like the ASPM

Time emerged as important in both a practical and a developmental sense. Firstly, in creating the topics, the ASPM frontloads the effort: both students said that lesson planning following the ASPM was far more focused and concise than it was if they had started with individual lesson plan proformas. Student A stated that lesson plans developed from an ASPM cycle could be 'one-pagers' because the underlying thinking had been done for the topic via the ASPM. Student A also spoke about it taking time to 'learn to like the ASPM': to develop knowledge and understanding of its purpose, the different elements, and how each person can use it to create their own pedagogical reasoning. Student A 'stopped resisting' the ASPM approach when its usefulness became clear and they stopped 'feeling daunted' by it. Student B also noted that 'the level of academia and the language sometimes… are quite daunting when you first get the [research] paper'. Thinking of the paper in parts helped: to think of the introduction, read the conclusion, and think about 'is this paper going to work for you' before moving on to read the whole article.

To begin with, Student A felt the class 'overthought' things when working with the ASPM. Student A initially felt lost in terms of where to start, even with the choice of topic: as this student developed practical understanding from placement choosing topics relevant to pupils, and being able to consider the ASPM more fully in terms of particular pupils. Student A said: 'I think that's maybe something that the ASPM's missing, is you know, how do you link that to *your* environment and *your* kids rather than just high level.' Student B thought that the better cycles of the ASPM were those in which the pedagogical approach at the end was not what you thought it would be at the start. Appreciating this evolves over time and seemed to rely on these students making the ASPM their own by developing a personal connection to it.

101.3 Theme 3: The challenges of connecting with evidence

Learning to connect with evidence was also an important but sometimes challenging aspect for the students. The importance of seeing evidence from reflection and practice as equally important to published research was mentioned by both. Student A mentioned how connecting with evidence felt a bit 'synthetic' to being with in year 1, and inauthentic. Student B noted challenges in engaging with published research papers in the early stages: 'initially it was really, really difficult… but the more I've done it, and the more I've seen the outcome, the more I've seen my own progression working with the ASPM'. Over time, Student B came to enjoy engaging with literature and then 'using that to enhance your practice'. Papers became valuable when this student 'connected' with something in the research (a 'lightbulb' moment), often, because they spoke in some way to challenges with pupil learning that Student B observed in the classroom (e.g. difficulties pupils had in moving between 2D and 3D representations). Both students spoke about connecting with published research in a different way for the ASPM than was the case for other academic assignments. Rather than sourcing evidence to explain something, their purpose shifted to what that evidence could offer to make their pedagogical practice more effective.

Both students spoke of the significance of reflecting on practice, and both referred to reflecting on how they learned when reasoning about subject pedagogy. Student B drew not only on teaching and learning experiences in formal education, but on professional experiences working with apprentices. Student A noted the importance of repositioning perspectives from the self as teacher/learner to foregrounding the needs of pupils. To begin with, Student A wrote their ASPM cycle too much from the perspective of what they had preferred and found effective as a learner. As Student A developed understanding and practice during year 3, they realised they had to take a perspective that was more focused on their pupils as learners. This student mentioned that their practice had been transformed through the process of developing pedagogical reasoning, giving the example of pupil misconceptions. Student A shifted their thinking from why a pupil does not know something that has been taught, to asking why is the pupil not understanding and what might need to be done to support them to understand. In creating the final pedagogical proposal, Student B spoke about a process of shifting what had been learned from the elements of the ASPM into a form that would support classroom practice.

102 CONCLUSIONS & IMPLICATIONS

These conversations highlight the importance of students creating personal connections with the processes of the ASPM. These connections seemed to relate to the value students felt the ASPM could bring to them as developing teachers and to their pupils. Renegotiating how they think about their own learning experiences and what their pupils require is important and is a process that develops over time. The students we spoke with ultimately had made the ASPM their own, finding their own ways to connect with literature, reflect, and evolve pedagogical proposals. In the next phase of conversations will help us to understand whether the importance of personal connection is particular to Students A and B, or whether this is something common to other students on the programme.

As teacher educators, we now wonder whether there are threshold concepts that students need to understand in order to develop a depth of knowledge over time that will then enable them to make the ASPM their own. For the participants, understanding the role of evidence seemed to be important to this process, particularly coming to understand that evidence will not always be confirmatory of what we think might be the best pedagogic approach. It may lead us to adopt approaches to pedagogy that we did not anticipate based upon experience alone.

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Grasping the Actual Situation of Student's Viewpoints on the Improvement of Manufactured Products and User Perspective in Material Processing Learning

Hisashi NAKAHARA, Oita University, nakaharah@oita-u.ac.jp
Keita SERA, Nara University of Education
Tetsuya UENOSONO, Hirosaki University
Atsuhiro KATSUMOTO, Hokkaido University of Education
Jun MORIYAMA, Hyogo University of Teacher Education

ABSTRACT

This study aims to comprehend the actual situation in materials and processing technology learning in junior high school regarding viewpoints on improving what has been produced and students' user perception after learning. The survey subjects were 833 junior high school students (8th-9th grade) in Japan. The results showed that about half of the students needed a user-oriented viewpoint of improvement after learning material processing. When the obtained free descriptions were functionally classified, three categories (self/family, specific user, all users) were established from the viewpoint of user perception. Specifically, most students with a user perspective focused on 'specific user'. The viewpoints to improve the products were classified into eight categories: 'safety', 'functionality', 'durability', and others regarding the improvement of products. In addition, the number of statements regarding the improvement of products was higher among the students who made the products freely. This indicates that students tend to develop their viewpoints of improvement and refinement through producing and using the products they have conceived and designed.

Keywords: Material and Processing Technology Learning, User Perception, Viewpoints on the Improvement of Products

1. INTRODUCTION

This study aims to comprehend the actual situation in materials and processing technology learning in junior high school (from now on referred to as 'materials processing learning') regarding viewpoints on improving what has been produced and user perception that students have after learning.

Curriculum guidelines indicate that learning to use views and ideas that are unique to technology, such as 'To understand the phenomena in daily life and society from the viewpoint of their relation to technology and to optimize technology by focusing on social demands, safety, environmental load, economic efficiency, etc' , in junior high school technology education (The Ministry of Education, Culture, Sports, Science and Technology, 2017a). Furthermore, in that study, 'To find problems related to technology in daily life and society and to set issues' indicates that the scope of the problem to be solved as technology education is the entire society, including industry, etc., as well as everyday life around us (The Ministry of Education, Culture, Sports, Science and Technology, 2017b). It is also indicated as 'To attempt to devise and create technology appropriately and with integrity'. It positions the importance of an attitude of trying to devise and create technology to build a better life and a sustainable society, not only by trying to realize personal wishes but also by being aware of the user's and creator's standpoints. From the above, it can be said that it is essential to cultivate an attitude of ingenuity and creativity with a view to the demands of society through the production, utilization, and evaluation of subject matter in learning activities such as the production and cultivation of manufacturing, etc.

In this context, The Japan Society of Technology Education, Japan's largest academic research organization for technology education, published 'The New Framework of Technology and Engineering Education for Creating a Next Generation Learning'(2022). In this recommendation, it is essential that the problem-finding and solving process of students developed in the classroom is isomorphic to the process of solving technical problems such as production, development, and invention developed in society and that the elements to be included in the problem finding and solving process should be in line with the engineering design process in society. The triple-loop model of the technical problem-finding and solving process is presented as a concept that embodies such an engineering design process. This is a loop that leads to the 'Social scientific needs exploration loop' and 'Experimental science seeds exploration loop', with sufficient learning and its results leading to the 'Creation of optimal deliverables loop' , and back and forth between the loops as appropriate. As a result, 'Cognitive Science' and 'Design Science' bridge in terms of the application of their findings and methods. In addition, it is essential for the 'Technological problem-finding and problem-solving process in line with the developmental stages of students' to situate the 'Problem finding and solving process using the triple-loop model' in the school curriculum. Expressly, it is noted that it is essential to cultivate the ability to identify and solve technical problems in line with the triple-loop model with elements such as user assumptions, needs identification, and seed exploration as developmentally appropriate technical activities are developed.

Thus, in the technology education curriculum, it is essential to incorporate problem-finding and understands needs by assuming users in carrying out projects through the engineering design process. However, in technology education in Japan, perspectives on understanding user assumptions and needs have yet to be considered necessary. Possible reasons include an emphasis on traditional classroom practices, insufficient class time, uniformity of subject matter, environmental improvement, lack of technological literacy development at the elementary school level, etc. Therefore, in this study, we attempted to understand in an exploratory manner what kind of viewpoints of improvement students may have after the fabrication of the manufactured product and actual utilization of the product in Learning technology education, and what kind of user perception they specifically have in that case. Specifically, we shall focus on material processing learning positioned first in junior high school, conduct a survey of students after the study., and examine how the difference in production subject expresses the description of user and product improvements.

104 SURVEY METHOD

The subjects were 833 junior high school students (8th-9th grade) in Japan. The survey was conducted using a web tool (Google Form). The data were tabulated after excluding those with incomplete or regular responses. 721 valid responses were obtained (valid response rate, 86.6%). The subjects of the survey were of three types: free design production subjects (from now on referred to as 'free production'), kit subjects who could choose from several productions (from now on referred to as 'choice kit'), kit subjects whose productions were unified (from now on referred to as 'unified kit'). Table 1 shows the specific contents.

We prepared the items for assessing students' experiences and consciousness. The prepared questionnaire for the survey had two parts: (1) Items for assessing consciousness and learning experiences in 'material-processing learning' and (2) Items for assessing viewpoints and user perceptions of manufactured product improvement.

Table 22.
Surveyed production and number of subjects

Type of production subject	Description	Target
free production	Free to design and produce own products. There are limitations on the size of materials used (e.g., laminated pine wood, L1800mm, W300mm, H15mm).	4 junior high schools, 366 students
choice kit	Choose from about ten different designs to fabricate. For example, choose from magazine racks, tissue boxes, accessory boxes, etc. There are limitations on the size of materials used (e.g., laminated pine wood, L1200mm, W150mm, H15mm).	2 junior high schools, 253 students
unified kit	Produce a designed book stand. The wood is vertically laid and requires little fabrication time. The size of the material is only just large enough to fabricate.	one junior high school, 102 students

Items for assessing consciousness and learning experiences in 'material-processing learning'

- I like making things ('like making things').
- I like the technology classes ('like technology classes').
- I like to think about concepts and design ('like concept and design'). 4) I am satisfied with my production in technology classes ('satisfied with my production').
- I would like to have a career in the future related to what I learned in my technology classes ('career in the future').

Items for assessing viewpoints and user perceptions of manufactured product improvement

- 'If you were a developer of a material processing product and wanted to improve the product you have made, for whom and in what areas would you improve it? Please describe freely without considering your skill level.'

The survey was conducted in technology classes by technology teachers in April 2022. Subjects rated their agreement in a survey (1), choosing one of the following four responses: 4, I strongly agree; 3, I agree; 2, I somewhat disagree; and 1, I strongly disagree. In a survey (2), respondents were asked to respond in the form of open-ended questions.

105 RESULTS AND DISCUSSION

Frequencies of acquired answers in Items for assessing consciousness and learning experiences toward 'material-processing learning' were counted to understand subjects' situations (Table 2). As a result, affirmative responses in 'like technology classes' showed the highest rate with 92.6%. On the other hand, affirmative responses in 'career in the future' showed the lowest rate with 41.5%. Next, the mean and S.D. were calculated. In addition to the overall trend, the data were tabulated by groups regarding the subject matter produced (Table 3). In addition, the data for (1) were tabulated for the overall and subject-specific groups. For 'like making things', the overall mean was 3.34 and S.D. was 0.64. A one-way analysis of variance by production subject showed a significant main effect of subject matter. Multiple comparisons using Bonferroni revealed significantly higher means for the Group of unified kit than for the Group of choice kit and the Group of unified kit than for the Group of free production. The overall mean for 'technology classes' was 3.33 and S.D. was 0.64. The main effect of the subject matter was significant, with significantly higher means in the Group of choice kit and the Group of unified kit than in the Group of free production. For 'like concept and design', the overall mean was 2.97 and S.D. was 0.77. The main effect of subject matter was significant, with significantly higher means in the Group of choice kit and the Group of unified kit than in the Group of free production. For 'satisfied with my production', the overall mean was 3.10 and S.D. was 0.69. The main effect of the subject matter was significant, with significantly higher means in the Group of choice kit and the Group of unified kit than in the Group of free production. For 'career in the future', the overall mean was 2.39 and S.D. was 0.77. No significant differences were found in the main effects of the subject matter. These results indicate that the subjects of this survey had a positive view of the manufacturing and technology classes and tended to be highly satisfied with the work produced in the classes. Comparison between groups showed this tendency was extreme in the Group of unified kit.

Table 2.
Frequency and rate of items for assessing consciousness and learning experiences toward 'material-processing learning'.

		frequency	rate
like making things	Positive	661	91.7%
	Negative	60	8.3%
like technology classes	Positive	661	92.6%
	Negative	60	7.4%
like concept and design	Positive	549	76.1%
	Negative	172	23.9%
satisfied with my production	Positive	600	83.2%
	Negative	121	16.8%
career in the future	Positive	299	41.5%
	Negative	422	58.5%

Table 3.
Means, Standard Deviations, and One-Way Analyses of Variance in assessing consciousness and learning experiences toward 'material-processing learning'.

		Mean	S.D.	ANOVA	Bonferroni	
like making things	all	3.34	0.64			
	unified kit	3.56	0.54		unified kit > choice kit	**
	choice kit	3.30	0.61	$F_{(2,718)}$= 6.82 **	unified kit > free production	**
	free production	3.31	0.68		choice kit free production	*n.s.*
like technology classes	all	3.33	0.64			
	unified kit	3.54	0.54		unified kit > choice kit	**
	choice kit	3.37	0.57	$F_{(2,718)}$= 9.49 **	unified kit free production	*n.s.*
	free production	3.24	0.70		choice kit > free production	*
like concept and design	all	2.97	0.77			
	unified kit	3.24	0.63		unified kit > choice kit	**
	choice kit	3.04	0.74	$F_{(2,718)}$= 11.69 **	unified kit free production	*n.s.*
	free production	2.85	0.80		choice kit > free production	*
satisfied with my production	all	3.10	0.69			
	unified kit	3.27	0.63		unified kit choice kit	*n.s.*
	choice kit	3.21	0.63	$F_{(2,718)}$= 12.4 **	unified kit > free production	**
	free production	2.98	0.73		choice kit > free production	**
career in the future	all	2.39	0.77			
	unified kit	2.53	0.80			
	choice kit	2.39	0.74	$F_{(2,718)}$= 2.02 *n.s.*		
	free production	2.36	0.79			

***p<.01, *p<.05*

Next, the free descriptions obtained in question (2) were classified into two categories: those related to user perception and those related to product improvement. The free descriptions obtained were classified into two categories: those related to user perception and those related to product improvement. An example description, 'To make the corners a little more shaved and rounded so that children can use it safely and not get hurt when touching it' was given to the student who made a toilet paper holder as a free production, 'Make it waterproof so that it will not break or get dirty when used in the kitchen for my parents who cook' to the student who made a spice rack as a choice kit, and 'I put various patterns and colours on it so that people of different generations can use it' to the student who made a bookshelf as a unified kit.

First, (1) the viewpoint of 'for whom' was classified as 'user perception', and (2) the viewpoint of 'what parts should be improved' was tabulated as 'viewpoint regarding improvement of manufactured products'. As a result, in the case of the description above, 'To make the corners a little more shaved and rounded so that children can use it safely and not get hurt when touching it', it was classified as (1) specific users and (2) safety. Similarly, in the case of the statement, 'Make it waterproof so that it will not break or get dirty when used in the kitchen for my parents who cook', we classified the statement into (1) self/family and (2) functionality. In the case of the statement, 'I put various patterns and colours on it so that people of different generations can use it', it was classified into (1) all users and (2) aesthetics.

When the data were tabulated in the above order, 364 descriptions (multiple responses: 326 respondents, 45.2% response rate) were received regarding user perception. When the obtained free descriptions were functionally classified, three categories were established from the viewpoint of user perception. The first was descriptions that focused on the lifestyle of family members, including oneself, and attempted to respond to the living environment and individual characteristics (from now on referred to as 'self/family'). The second category was descriptions that focused on needs arising from psychological and physical characteristics derived from age groups, personality and physical characteristics derived from individuals, lifestyles, preferences, occupations, social roles, etc. (from now on referred to as 'specific user'). Lastly, the descriptions considered users in an all-encompassing manner, such as universal design (from now on referred to as 'all users'). The response rates were compared among the groups, and no significant differences were found (Table 4).

There were 956 statements (multiple responses; all valid responses) regarding fabrication product improvement. The free descriptions were classified functionally in the same way as user perception and were classified into eight categories: Safety, Durability, Functionality, and others. Table 5 shows the categories and examples of the descriptions. Overall, the 'Safety' category received the highest responses, followed by 'Durability' and 'Functionality' (Table 6). A comparison between the groups of production subjects showed significant differences in response rates in 'Functionality' and 'Quality' improvement categories. Comparisons were also made by dividing the groups into those that described the user perspective and those that did not (Table 7). As a result, significant differences in response rates were found in the categories of 'Safety', 'Durability', 'Convenience', and 'Aesthetics'. These results indicate that students' perceptions of users tend to focus on specific needs. In addition, it was found that the viewpoints on the improvement of the manufactured products varied depending on the subject matter of the product.

Table 4.
Frequency of responses and chi-square results of user perception

	All (N=721)		free production (n=366)		choice kit (n=253)		unified kit (n=102)		Comparison between groups	
	frequency	rate	frequency	rate	frequency	rate	frequency	rate		
self/family	21	2.9%	14	3.8%	7	2.8%	0	0.0%		*n.s.*
specific users	234	32.5%	127	34.7%	73	28.9%	34	33.3%	$\chi^2_{(2)}$= 2.37	*n.s.*
all users	91	12.6%	48	13.1%	34	13.4%	9	8.8%	$\chi^2_{(2)}$= 1.57	*n.s.*
Total number of statements	346	48.0%	189	51.6%	114	45.1%	43	42.2%		
Total Number of Writers	326	45.2%	179	48.9%	109	43.1%	38	37.3%	$\chi^2_{(2)}$= 5.09	*n.s.*

Fisher exact test was used for those with 0 in the observed frequencies

Table 5.
Category types and examples of descriptions

category	Example of description
Safety	Rounded edges with no sharp edges to prevent children from hurting themselves.
Functionality	More compartments to hold different things.
Durability	Make it sturdy so that it will not break even if it falls.
Convenience	Make it light so that it can be carried and moved easily, even by those who are not strong.
Quality	Varnish the surface to improve the feel, as a rough surface is not good.
Aesthetics	Create a variety of colors to improve the appearance of the product.
Environmental	Use environmentally friendly materials.
Economy	Consider the materials to be used to reduce the cost.

Table 6.
Frequency of responses and chi-square results of analysis of categories related to viewpoint regarding improvement of manufactured products (comparison between the groups of production subjects)

	All (N=721)		free production (n=366)		choice kit (n=253)		unified kit (n=102)		Comparison between groups	
	frequency	rate	frequency	rate	frequency	rate	frequency	rate		
Safety	326	45.2%	168	45.9%	105	41.5%	53	52.0%	$\chi^2_{(2)}$= 3.35	*n.s.*
Functionality	248	34.4%	148	40.4%	81	32.0%	19	18.6%	$\chi^2_{(2)}$= 17.79	**
Durability	164	22.7%	83	22.7%	56	22.1%	25	24.5%	$\chi^2_{(2)}$= 0.24	*n.s.*
Convenience	112	15.5%	52	14.2%	40	15.8%	20	19.6%	$\chi^2_{(2)}$= 1.80	*n.s.*
Quality	53	7.4%	39	10.7%	14	5.5%	0	0.0%		**
Aesthetics	49	6.8%	29	7.9%	17	6.7%	3	2.9%	$\chi^2_{(2)}$= 3.13	*n.s.*
Environmental	3	0.4%	1	0.3%	0	0.0%	2	2.0%		*n.s.*
Economy	2	0.3%	2	0.5%	0	0.0%	0	0.0%		*n.s.*
	957	132.7%	522	142.6%	313	123.7%	122	119.6%		

**p<.01 Fisher exact test was used for those with 0 in the observed frequencies

Table 7. Frequency of responses and chi-square results of analysis of categories related to viewpoint regarding improvement of manufactured products (Group with description or no)

	All (N=721)		Group with description (n=326)		Group with no description (n=395)		Comparison between groups	
	frequency	rate	frequency	rate	frequency	rate		
Safety	326	45.2%	183	56.1%	144	36.5%	$\chi^2_{(1)}$= 27.91	**
Functionality	248	34.4%	114	35.0%	134	33.9%	$\chi^2_{(1)}$= 0.09	*n.s.*
Durability	164	22.7%	52	16.0%	112	28.4%	$\chi^2_{(1)}$= 15.64	**
Convenience	112	15.5%	72	22.1%	40	10.1%	$\chi^2_{(1)}$= 19.47	**
Quality	53	7.4%	19	5.8%	34	8.6%	$\chi^2_{(1)}$= 2.03	*n.s.*
Aesthetics	49	6.8%	13	4.0%	36	9.1%	$\chi^2_{(1)}$= 7.41	**
Environmental	3	0.4%	1	0.3%	2	0.5%	$\chi^2_{(1)}$= 0.17	*n.s.*
Economy	2	0.3%	2	0.6%	0	0.0%		*n.s.*
	957	132.7%	456	139.9%	502	127.1%		

**$p<.01$ Fisher exact test was used for those with 0 in the observed frequencies

106 CONCLUSIONS AND FUTURE ISSUES

In this study, the following findings were obtained from an open-ended survey of students' viewpoints on improving manufactured products and their perceptions of users after learning materials processing in the technology education.

About half of the students needed a user-oriented viewpoint of improvement after learning material processing. On the other hand, most of the students who had a user perspective focused on ‘specific users,’ or in other words, on usability. Moreover, no differences were found when the production subjects compared the user perceptions. From these facts, it can be pointed out that, as in free production, it is not possible to assume a variety of users because conceptual and design activities are performed, but the importance of appropriately positioning learning about the demands of society and learning to identify problems by envisioning users and understanding their needs can be pointed out. The viewpoints to improve the products, such as ‘safety’, ‘functionality’ and ‘durability’ were formed regarding the improvement of the products. In addition, the number of statements regarding the improvement of products was higher among the students who made the products freely. This indicates that students tend to develop their viewpoints of improvement and refinement through producing and using the products they have conceived and designed. Furthermore, the subjects differed in their viewpoints on product improvement. Specifically, it is considered essential to learn more about ‘functionality’ and ‘quality’ in the case of a unified kit and ‘safety’ in the case of a choice kit.

However, since this survey did not allow for comparisons of the same sample size regarding grades and production contents, more detailed surveys are needed. In addition, detailed analysis (e.g., text mining) will be conducted, and surveys will continue to be conducted to understand the actual situation in other learning contents.

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Timeless, Socially Relevant Engineering Knowledge and Skills for Future Technology Education

Per Norström, KTH Royal Institute of Technology, perno@kth.se
Susanne Engström, KTH Royal Institute of Technology, sengstro@kth.se
Birgit Fahrman, KTH Royal Insitute of Technology, birgitf@kth.se

ABSTRACT

The aim of technology education in primary and secondary school is that students should acquire skills and knowledge that are useful not only today, but also when they are adults. Students' knowledge and skills need to include aspects of engineering and crafts as well as social implications of technology, which together develops creativity, useful everyday skills, critical thinking, and more. This leads to special challenges for technology teacher education, which has to look forward and focus on future challenges. The training needs to include timeless skills and be both about and for the technological future. Exactly which knowledge and skills that are best suited for this endeavour is not in any way clear. The purpose of this paper is to find the timeless and socially relevant engineering methods and skills that could and should be taught in primary and secondary school to increase the likelihood that students are properly prepared for the future. The project has an exploratory approach. Data were collected through focus group interviews with different participant groups: technology teachers in lower and upper secondary school, teacher students aiming to become technology teachers, and teachers working in academic teacher training programmes. The results show that the question about timeless knowledge has rarely been discussed in these groups. They had no clear answers, but ended up mainly in traditional technology education content: writing technical reports, learning strategies for design and product development, and fundamentals of computer programming. The results suggest that the respondents believed strongly in pupils' ability to transfer skills and knowledge between domains.

Keywords: technology education, engineering education, timeless knowledge, future education

1. INTRODUCTION

Modern technology education in primary and secondary school took off in the 1980s and 1990s, and spread across the world. The subjects vary considerably between countries, but generally emphasize crafts, engineering science, and societal aspects of technology (Nordlöf et al., 2022). Compared with older school subjects such as physics and mathematics, there is little consensus concerning its contents. Focus varies between countries, with well-known examples such as Scotland and Finland emphasizing crafts, Massachusetts emphasizing computers and modern engineering, while Sweden's and New Zealand's curricula stress the history and sociology of technology (Norström, 2022). All technology subjects share several challenges. One that has received a lot of interest from the education research community is the (sometimes) complicated relationship between technology and the natural sciences in educational contexts. Another well-researched area is the role of design work in technology education. Other problems, that have not received the same amount of attention, include the question of timelessness and durability of technological knowledge.

In Sweden, what pupils learn about technology in school at the age of 13 should be useful in their everyday lives, but also aid them in choosing a suitable branch of secondary education at the age of 16, and to understand political, ethical, and practical technological problems throughout their adult lives. For this to be possible, what they learn has to have some degree of timelessness. Predicting the technological future – and the knowledge necessary to understand it and act in it – has proven difficult for engineers as well as for historians and sociologists of technology (cmp. Bowler, 2017). In the early 2000s, many experts claimed that ethanol was soon to replace fossil fuels. Ten years later, other experts ascertained that autonomous vehicles would fill roads and streets within just a few years. Technology textbook authors also make erroneous predictions of the future. In commonly used Swedish upper secondary school textbooks (Frid, 2011; Nyberg, 2011), obsolete 3D manufacturing methods are described along the soon-to-come technological revolutions enabled by the mass-production of graphene. Attempts to include future technologies and methods in the teaching risk making it seem abstract and irrelevant, as it is difficult to relate to today's world. If the predictions turn out to be incorrect, they risk becoming ridiculous. ITEA addresses the problem of prediction in their *Standards for technological literacy* (2007, p. 1):

> Because technology is so fluid, teachers of technology tend to spend less time on specific details and more on concepts and principles. The goal is to produce students with a more conceptual understanding of technology and its place in society, who can thus grasp and evaluate new bits of technology that they might never have seen before.

Exactly which knowledge, skills, 'concepts and principles' that are best suited for this endeavour is not in any way clear, and the standards are not helpful with concrete advice for how to make the aspirational learning take place. Instead, it has to be developed mainly in the community of technology teachers, teacher educators, and curriculum designers.

The purpose of this paper is to find the timeless and socially relevant engineering methods and skills that according to teachers and teacher educators could and should be taught in primary and secondary school to increase the likelihood of pupils' being well prepared for the future. The study is planned as the first step in a larger project about timeless technological knowledge. It has an exploratory approach and uses focus group interviews. The number of respondents is low, but they represent different groups within the technology education community. Thereby, they approach the opportunities and difficulties concerning timeless, socially relevant engineering knowledge and skills for future education in different ways.

The study should answer the following questions:

- What characterises timeless and society-relevant knowledge in the technology subject according to technology teachers, technology teacher students, and technology teacher educators in Sweden?

- How do they work to implement this?

The study is mainly descriptive. The results will be useful as inspiration for teachers, teacher educators, curriculum designers and for future research in technology education.

2. TECHNOLOGY EDUCATION IN SWEDISH SECONDARY SCHOOLS

In Sweden, technology is a mandatory subject for all pupils throughout the nine years of compulsory schooling. The contents have a wide scope. For the youngest pupils, focus is on everyday technologies. In lower secondary school (years 7–9; pupils are 13–16 years old) pupils study the design process, infrastructure, modern materials, automatic control using programmable systems, the relationships between technology, the arts, and the natural sciences, and more (Skolverket, 2022).

In upper secondary school, technology is a subject for students who have chosen the technology programme (c. 8–10 % of the student population, with considerable geographic variation). While technology education in compulsory school is for everyone, the explicit purpose of upper secondary school technology is to prepare for future studies and work in the domains of technology and engineering (Skolverket, n.d.).

3. DATA COLLECTION

Data were collected through focus group interviews with selected groups from the educational community. Using focus group interviews enable the respondents to discuss and develop their responses together. Through their conversation, they express their understanding and through the jointly conducted dialogue, the responses are developed further. The interviewers can ask questions to encourage clarification, and nudge the respondents if the conversation comes to a halt. Having a safe environment for the interview is important (Marshall & Rosman, 2011). The focus-group interviews in this study were carried out mainly at the respondents' workplaces. The respondents are well acquainted with each other – they are colleagues at a school, students in the same education programme, or teacher educators who meet regularly.

3.1 Respondents and interview procedure

The respondents consisted of four groups, gathered through convenience sampling:

- *Lower secondary school technology teachers*. Three experienced teachers, working in a municipality-owned school in an upper middle class area.

- *Upper secondary school technology teachers*. Three experienced teachers, working in a municipality-owned school, specialised in computer science and invention.

- *Technology teacher students*. Nine former engineers, participating in a bridging teacher education programme at a Swedish university with the aim of becoming secondary school teachers.

- *Technology teacher educators*. Five teacher educators (lecturers, senior lecturers) representing 4 different higher education institutions.

The keywords 'timeless, socially relevant engineering knowledge and skills for future education' were written on a whiteboard (in Swedish). These words served as a starting point for the discussion, and both interviewers and interviewees returned to them during the conversation. Each group-interview lasted between 30 and 60 minutes. The interviews were recorded (audio only), and transcribed verbatim. Data collection took place during the autumn of 2022, and the spring of 2023.

3.2 Data analysis procedure

The interview transcripts were analysed using thematic analysis, inspired by Braun and Clarke (2006). The three authors read the transcripts repeatedly. Recurring themes were identified. Thereafter, notes and themes were compared, and similar themes combined. This enabled both the content of what the respondents brought up to be framed, and also emphasized the interactive qualities of the conversations.

4. RESULTS AND ANALYSIS

When comparing the themes from the different groups of respondents, both similarities and differences came up. This concerns both what kinds of themes that were discussed, and how they were addressed. The secondary school teachers highlighted examples from their own teaching practices. They returned to what pupils would find interesting or difficult several times. They also made more frequent references to the curriculum documents than the other groups. The upper secondary school teachers stressed the need to be skilled in maths for a future career in technology, which the lower secondary school teachers did not. The teacher educators focussed on the challenges of teachers and teacher students. They talked about how teachers should stand up and be proud of their subjects, and the need for courage and self-confidence for the ability to teach. The participating teacher students, of whom many had recently worked in engineering, often referred to their own experiences as pupils and students. Just like the upper secondary school teachers, they mentioned maths as essential for a career in technology or engineering, but also self-confidence, initiative, and an attitude of curiosity.

The respondents were not used to discuss the abstract concept of timeless knowledge, or even knowledge that would stay useful over time. In many cases, the discussion drifted towards engineering skills. Social, historical, and ethical knowledge stayed in the background for most of the time.

Below, the themes that emerged from the entire material, across all participant groups, are presented. Thereby, we aim to highlight what characterises timeless and socially relevant engineering skills and knowledge, suitable to address in technology education in secondary school, as interpreted by respondents involved in technology education in various roles. The themes below are not discrete, but overlapping.

4.1 Timeless knowledge areas within the Swedish technology subjects

The respondents highlighted certain technological areas where it was especially important that pupils should develop knowledge and skills. These were referred to as 'timeless' or 'likely to be useful in the future', but also as 'necessary for all engineers', and referred to as 'indispensable parts of technological literacy'. The most commonly mentioned areas were computers and programming; electronics; energy; and mechanics. The lower secondary school teachers mentioned houses and the built environment in general. The upper secondary school teachers mentioned the history of technology. Surprisingly enough, none of the groups talked at length about infrastructure or large technological systems.

A rudimentary knowledge of computers and computer programming (by some respondents referred to as 'computational thinking' or 'general digital competence') was emphasised by all groups. Fundamental programming skills and concepts such as variables, conditional statements, and loops were considered important to understand, and believed to withstand the test of time. The secondary school teachers mentioned common electronic components, their names, and use. Especially the upper secondary school teachers stressed the need to understand how components are combined with computers and processors to perform automatic control tasks.

Both teachers and teacher educators mentioned classical mechanical technological solutions such as levers, inclined planes, and screws. One of the teachers reminded their group that they are truly timeless: 'They have been at the core of technology education since antiquity, and will be used forever.'

Energy, especially the production of electricity, was also mentioned numerous times. The discussion never really took off however. The reason for this could be that energy, energy distribution, and energy politics, traditionally belong to the subjects of physics and civics in Swedish curricula.

Other knowledge areas mentioned in passing include knowledge of the history of technology, ethical aspects related to technology, knowledge of various standards, materials, and durability.

4.2 Timeless methods, procedures, and skills

It was obvious that the respondents found it easier to discuss timeless methods, procedures and skills, compared with propositional knowledge. Several times, strong beliefs in the possibility of transferring a method or skillset from one domain to another were expressed. This concerned areas such as the writing of technical reports ('They look more or less the same, no matter what kind of technology they deal with') to a general engineering design process, applicable for many kinds of technical problem solving or product development tasks.

Teaching of a structured design process has been the core of technology education in many countries for a long time (probably most notable in the United Kingdom). The Swedish technology curricula have always described a broader subject, in which design and product development is just one theme among others (history of technology, large technical systems, the relations between science and technology, etc.; Skolverket, 2022). Nevertheless, even in Sweden the learning of a design process is considered essential and timeless technology education content. The upper secondary school teachers mentioned how design and product development work encourage curiosity and provides a framework for learning about technology in general. The lower secondary school teachers also mentioned this, for example in relation to learning about how to write technical reports and how to use flowcharts and technical drawings. The teacher students talked about the importance of learning how to collaborate, and how design and development work could provide an environment for this.

The upper secondary school teachers, who were keen on programming, mentioned software engineering as an important form of design or product development work. They described the skills and the attention to detail needed for systematic testing, analysis, and debugging of software as to some degree transferrable to other technical domains. Furthermore, the upper secondary school teachers meant that product development work encouraged information retrieval and critical thinking. If the project is large enough, and authentic enough, pupils will repeatedly run into problems that neither they nor their teachers know how to solve: 'Google, and see what you can find. There is a lot of rubbish out there, but also useful stuff. You learn how to find it by trying.' Environmental awareness, life cycle analysis, risk assessment, and mathematical and physical modelling are also considered timeless skills that can be practiced in a design process environment.

107.1 Attitudes

Despite our question focusing on knowledge and skills, the need to develop sound attitudes towards technology and engineering was brought up numerous times. The respondents described how a timeless, socially relevant, engineering-focussed attitude must be positive towards and comfortable with technology; it is characterised by a desire to investigate, discover, and solve problems, as well as to understand one's choices and being able to create technology oneself. The individual and their opportunities that each person can gain through an innovative attitude are in focus.

Skills such as analysing environmental impact or ethical implications of technologies was mainly discussed through attitudes. The respondents discussed the need for pupils to develop an environmental awareness, and recognize their own (and the Western world's) roles in the technosphere. They did however not discuss how this could be done, or how these attitudes could encourage scientific evaluation of the impact of lifestyle choices or new innovations. The suggestions never went beyond developing an awareness of possible problems, and an attitude implicating that a solution can be found.

An attitude towards technology that will withstand the test of time is also described as action-oriented, curious, and insightful about how the world works. Throughout the education, students should be encouraged to develop a personal desire to learn and a willingness to face technical problems that they cannot yet understand (preferably socially relevant ones). According to the respondents, an innovative, self-directed, and playful attitude is important for students' will and abilities to approach timeless, socially relevant, and engineering aspects with their 'problem-solving mental toolkits.'

5. DISCUSSION

During the last decades, the most important way of educating technology teachers in Sweden has been through re-training of engineers. The group of respondents reflects this. Almost all of them have some kind of background in engineering: the upper secondary school teachers were all former engineers who had re-trained to become teachers, the teacher students were former engineers, as were a majority of the teacher educators. This has most likely affected the results, as most discussions started out with an engineers' view of technology, rather than that of an artisan, an economist, a historian, a politician, or an average citizen.

The task set in front of the respondent groups proved to be a difficult one. Trying to frame parts of the Swedish technology subjects is always difficult, as the contents cover wide areas of knowledge, the content has changed considerably with every new version of the national curriculum, and the subject's informal canon of content and exercises is weak. It does not get any easier if the task is not to describe just what content that would be useful today, but also what would be useful in the future. Many predictions about the technological future have proven wrong, and it is of course difficult for technology teachers to determine what the technological future will look like. What constitutes the 'more conceptual understanding of technology [that enables pupils to] grasp and evaluate new bits of technology that they might never have seen before' (as ITEA, 2007, p. 1, put it)? That gears, inclined planes and screws belongs there seems likely. But what more? Technical reports will most certainly be written in the future, but will they be written by humans? Autocad and Microsoft Word have been around since the early 1980s, will they still be widely used ten years from now? The respondents in this study, i.e. groups of technology teachers, technology teacher students, and technology teacher educators stressed that knowledge about mechanics, electronics, and elementary computer programming was timeless. This content already have prominent positions in the Swedish curricula. The respondents did not talk about specific tools, but general concepts. 'Timelessness' was however not elaborated upon beyond the almost trivial 'useful in the future'. The respondents could provide examples of knowledge that they considered timeless, but obviously found it more difficult to motivate their choices or suggest an overarching description of what united them.

This is a work in progress. In a near future we will deepen our understanding of what the educational community thinks about timeless, socially relevant knowledge and skills in technology. The next step will be to interview stakeholders such as industrial companies and institutions of higher technical education. The results will be useful for curriculum design and educational development, and could provide input to a general discussion about the purpose of technology education in school.

When both society and technology changes rapidly, teachers and teacher educators will have to make several difficult choices. Should we teach about technologies for a world with higher temperatures, lack of drinking water, microplastics in the oceans, less political stability, and no fossil fuels? Or should we teach about technologies for a world where everyone is a happy vegetarian, surviving on organic food from the local co-op, travelling only on bicycles built from recycled cardboard? Something in between? That is a choice for politicians and curriculum developers. Hopefully, this study can inspire to further studies within the area.

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"The main thing is practical work": Teachers' Beliefs Supporting the Intellectual Development of Technology Education

Isabelle Penning, University of Potsdam, isabelle.penning@uni-potsdam.de

ABSTRACT

Although technology shapes our world comprehensively, technical education has hardly been discussed in Germany in the special context on mental development. Even though technical education is anchored in the curriculum, it is not yet known which beliefs teachers at special schools have about technical education. Teachers' beliefs play an important role in teachers' attitudes towards student thinking and how lesson content should be selected and taught. These beliefs were assessed in the present study via a qualitative research design involving teachers from special schools in Germany (N:9). The results indicate that technical education is strongly practice-oriented and is mainly used to teach manual skills and work-related soft skills. The production task plays a special role here, as it proves to be a consistently important method in teachers' estimation. In the production process, teachers provide various forms of material and personal support. The aim is for pupils to achieve a successful and finished product and in the process experience themselves as successful. This production process requires a high degree of flexibility on the part of teachers regarding both the competence levels of the pupils and the technical requirements. Important suggestions can be derived for the conceptual design of inclusive technical education, paying greater attention to pupils' individual needs. At the same time, however, the results point to a need for qualification, since teachers predominantly focus on only one specific area of technical competence. The goal of technical literacy intended for technical education programmes does not yet seem to be sufficiently achieved in the context on mental development.

Keywords: intellectual development, teacher beliefs, teaching practice, differentiation, assistive technologies

1. TECHNICAL EDUCATION IN THE SPECIAL CONTEXT OF MENTAL DEVELOPMENT

In order to promote emancipation and technological maturity, a general technical education is necessary for all pupils. The objective of general technical education is to enable pupils to deal responsibly and maturely with technology, including its design and evaluation. Maturity means being able to take responsibility in a world shaped by technology and to act appropriately, humanely, and in solidarity with others (Bienhaus, 2008, p. 6): striving for technological literacy enables an individual to engage with the many facets of the cultural field of technology (Stuber & Käser, 2019, p. 22).

In Germany, three approaches to technical education emerged in the 1970s: the general technological approach, the multi-perspective approach, and the work-oriented approach (Schmayl, 2019, pp. 124, 128, 133). In addition to addressing specific questions of method and content, which vary among the approaches, together they also shape the curricular anchoring of technical education in both independent and integrated subjects. In Berlin and Brandenburg, the federal states in which this study was conducted, technical education is linked with the integrated subject of business-work-technology and has historically developed around a work-oriented concept. In the work-oriented approach, the focus is less on technological reference points (e.g. design principles) and more on usability in the context of work (Zinn, 2018, p. 66). Workplace analyses, product analyses, and projects are core teaching methods and interdisciplinary teaching is favoured (Geißel, 2018, p. 219).

Despite educational efforts in the context of inclusion, the majority of pupils with intellectual disabilities in Germany are taught in special schools (Kultusministerkonferenz, 2022, p. XXII). However, due to the German educational system, the concepts followed to implement inclusion vary greatly from one federal state to the next, as does the rate of inclusion. Nevertheless, it can be stated for the special context of mental development in Germany that special schools are still an important place of education.

In the german school system the first exposure to technology-based content takes place in the general subject lessons (grade 1-4). From grade 5 (in the state of Brandenburg) or grade 7 (in the state of Berlin), pupils receive instruction in the subject of economics-work-technology studies (WAT). Here, the key competence "the pupils plan and manufacture products" (SenBildWiss Berlin & LISUM, 2011, p. 100) is identified for the special focus of mental development in the area of technical education, which is supplemented by the following subject areas:

- Materials and supplies
- Tools and technical equipment
- Product creation
- Hygiene measures and safety regulations (SenBildWiss Berlin & LISUM, 2011, p. 100)

Figure 1 Overview of the anchoring of technical education in the German school system for people with intellectual disabilities

grade	age	anchoring of technical education
12 [2] 11	17 16	Final level/ two-year prevocational training course “Berufsqualifizierender Lehrgang (BQL)”
10 [1] 9 8 7	15 14 13 12	subject economics-work-technology studies “Wirtschaft – Arbeit – Technik (WAT)“
6 5	11 10	
4 3 2 1	9 8 7 6	technology-based content included in the general subject lessons

Focus of this study: determine teacher beliefs’ of compulsory technical education

[1] end of compulsory education
[2] end of compulsory vocational education

After the 10th year of school attendance, the pupils have completed their compulsory education. In order to fulfil their compulsory vocational schooling, two further school years follow, in which other curricular requirements come into play. Often these last years of schooling are completed at the same school, but sometimes also at a special vocational school. This school stage focuses on vocational orientation and preparation for life after school (Stöppler & Schuck, p. 2). In Berlin and Brandenburg, this stage is also referred to as the two-year prevocational training course “Berufsqualifizierender Lehrgang” (BQL) in the curricula (2013). Vocational qualifications are already taught here for a wide range of occupational fields. In the technical field, these include woodworking, ceramics, and metalworking.

108 IT'S THE TEACHERS WHO MATTER

Up to now, only a few studies have researched the intersection between technical education and inclusion. Even for the STEM subjects, which are widespread in the international context, there is also a great lack of research with regard to pupils with disabilities (Hwang & Taylor, 2016). In addition to studies on the effects of intervention programmes (Gottfried et al., 2016; Kolne & Lindsay, 2020; Theobald et al., 2019), barriers to access and participation in STEM programmes have also been identified (Dunn et al., 2012; Klimaitis & Mullen, 2021a). However, these studies do not specifically focus on technical education, nor do they explicitly refer to people with intellectual disabilities. Previous approaches to inclusive technical education in Germany are mostly of an older vintage (Duismann, 1992; Kuipers, 1984) and/or treat technical education from the perspective of the integrated subject of economics-work-technology studies (Duismann, 1981; Fischer & Pfriem, 2011; Mertes, 1984; Penning, 2023). Schaubrenner (2021) examines stress factors in inclusive teaching and their management via teacher training. Schaubrenner's theoretical-conceptual considerations on technical work in classroom workshops are of particular interest for this article (Schaubrenner, 2018a; 2018b). His results indicate that especially classes in workshops are particularly challenging for teachers and must be tailored to the individual needs of each pupil.

Although teachers at special schools teach technical education, little is known about their actual teaching practice and beliefs towards technical education. Particularly in the STEM subject, research has studied teachers' perceptions towards the subject in different countries and grade levels (Bell, 2015; Hsu et al., 2011; Park et al., 2017; Wang et al., 2020; 2011), as well as intervention measures to change teacher beliefs (Rich et al., 2017). In the field of technical education, teachers' beliefs about the use of robotics (Sullivan & Moriarty, 2009) and 3D printers have been studied (Cheng et al., 2020). There is no known survey of teachers' beliefs of the implementation of technical education in special schools, and therefore this is the focus of the current research project.

109 METHODOLOGY

The current research project investigates the following question: What beliefs do teachers at schools for intellectually and mentally disabled children have about technical education? A qualitative research approach was chosen to answer the research question.

109.1 Theoretical standpoint

Teachers' beliefs express what a teacher believes, what he or she trusts, what he or she subjectively considers to be correct and with which subject-related pedagogical ideas, views, world views and values - with which professional ideal - he or she identifies (Reusser & Pauli 2014, p. 644). Teacher beliefs integrate values held to be true and significant regarding pedagogical and subject educational responsibilities in teaching and learning processes, perceptions of role identities of learners and teachers, and assumptions regarding specific learning content and educational topics of their subject domain or overarching competency fields *(Reichhardt 2018, p. 76)*.Teacher beliefs can have a significant impact on teaching and student learning, as they guide a teacher's decisions and actions and are thus likely to yield insights into classroom practice. They have three main functions as (1) filters, (2) frames, and (3) guides for teachers' actions in the classroom (Fives & Buehl, 2012, p. 478).They can also become barriers to reforms (Kirchner, 2016, p. 114). Understood as an essential dimension of the professional competence of subject-specific teachers, they can be used to draw conclusions for teacher training and continuing education, as well as to identify common ground between school practice and subject didactics (Kirchner, 2016).

109.2 The sample

The sample of N:9 consists of teachers practicing in German special education schools in the federal states of Berlin and Brandenburg. In the sampling plan, a variance was aimed at with regard to the inclusion of both federal states, public and public schools, with regard to gender and the amount of professional experience in years.
During the research, it became clear that the structural division between WAT teaching in the compulsory education sector (grade 5-10) and at the vocational qualification level (grade 11-12, BQL) was hardly present in the sample. Thus, four BQL teachers responded to the interview call, even though it was specifically directed at WAT teachers. Two teachers taught both BQL and WAT. What is striking is that the majority of teachers surveyed only taught a sub-area of WAT. Many of the teachers reported exclusively on their activity in the workshop, which relates to the

processing of only one material. Most of them teach woodworking and some are also responsible for the maintenance of the classroom workshops. Occasionally, there were reports of other content areas of the WAT lessons or class leadership activities and lessons in other subjects. This might be explained by the interviewer's explicitly stated interest in technical education. However, since it is precisely this informal type of specialisation that is emphasised as a problem of compound subjects (Kirchner, 2023), it should be examined more closely in subsequent studies.

109.3 The data collection and analysis

A semi-structured interview according to Witzel & Reiter (2022) was developed. The interview guideline included open questions and narrative impulses and contained central didactic aspects such as competence orientation, didactic principles, choice of methods and media, among others (cf. table 1).

Table 1.
Excerpt from the interview guideline

What do you like most about teaching WAT?
Please tell me about a particularly successful WAT lesson
In your opinion, what are the special features of WAT lessons with pupils who have a special focus on mental development?
Which competences should your WAT lessons promote at best?
Which teaching methods do you think are particularly suitable for teaching WAT in the special focus of mental development?
Are there special didactic principles that are particularly important to you in your WAT lessons?

The interviews were subsequently transcribed and evaluated with the help of qualitative content analysis following Mayring (2022). Inductive category formation was used with the help of the Atlas.ti software.

110 TEACHER BELIEFS ABOUT TECHNICAL EDUCATION

110.1 Technical education is predominantly interpreted as leading to vocational qualification

The results make clear that the teachers place a particularly high value on practical craftmanship activities. They describe the special potential of practical crafting activities for the specific target group as a promising approach to learning as opposed to theoretically oriented teaching. They emphasise the great importance of "creating workpieces" for the pupils' sense of pride.

Through practical activities, pupils not only experience themselves as self-effective, but can also receive positive feedback from outsiders. Their achievements become visible through their workpieces. In addition, the practical approach is based on an orientation towards the future, which for the students primarily means working in a workshop for disabled adults. Such workshops are special systems of vocational rehabilitation and integration in Germany. In order to be well prepared for this, interdisciplinary learning goals such as perseverance, frustration tolerance, and independence are aimed at during instruction. Naturally, technical and manual skills are also emphasised. Interesting here is the emphasis on precise production and attention to detail, which is perceived in opposite ways by individual teachers: while for one teacher a high degree of dimensional accuracy is a central goal for vocational qualification, another teacher argues that the focus should be on promoting independence and self-efficacy.

Even if this strong vocational focus need only be the subject of teaching at the vocational qualification level, it also characterises the design of a WAT lesson, or cannot be distinguished from it. The main subject-related objectives are material and tool knowledge, specific production techniques including safety aspects, and independent planning of the work process. Teachers' beliefs' here vary regarding the scope of the planning steps. Some teachers involve the learners in the mental structuring of the entire production process "from the raw wood material to the finished object", for example, considering the procurement and cost of materials. Others focus on planning the day-to-day, concrete work steps. Here, the main focus is on enabling pupils to make an appropriate choice of materials and tools using the production techniques they have already learned. Finally, small-step processes also need to be planned, such as first measuring and marking the wood before drilling.

In the interviews, only non-digital production techniques are reported and, apart from the standing drill and scroll saw, mostly hand tools are used. Working on fast-running machines, such as a circular saw or band saw, is permitted by the accident insurance agency of the federal states of Berlin and Brandenburg from the age of 14, but is not mentioned by the teachers. Particularly with regard to the target group, special reference is made to the need to get used to noise when using machines. Some pupils find it difficult to tolerate the background noise. While some pupils have no sense of danger, others have a mild or intense fear of the machines, so their independent use by the pupils in itself is considered a success.

110.2 Designing differentiated teaching-learning processes

A variety of methods are used to tailor lessons to different students' needs, concentrated exclusively around the manufacturing task. When alternative methods are mentioned, their use is always closely linked to the manufacturing task, such as teaching the use of a stationary drill. The differentiated measures for production-related tasks range from dividing pupils into very small learning groups (rarely more than five pupils), restricting access to machines (besides the stationary drill, usually hand-held maschines), consciously selecting the tools and materials, and providing personal assistance. In particular, pupils' individual interests are taken into account in the selection and design of the products they will make.

The teachers explain that they build the object themselves during lesson preparation in order to analyse the manufacturing requirements in detail and plan their support for the pupils. Particularly when the teachers base their products on real needs, for example, of the school community, they sometimes take over individual production steps themselves in order to ensure that the remaining steps fit their pupils' performance level. The teachers state that a high degree of flexibility is required despite this extensive preparation. Only during the lesson does it become obvious where challenges lie.

During the production process itself, aids are used to compensate for the pupils' motor impairments or low level of competence in measuring and thus to increase the pupils' independence. In addition to personal support in the form of manual guidance, verbal instructions are given. Visualisations support the teaching process and partly also the production process. Learning from the teacher's model, which demonstrates the production steps, is very important, as is the repeated practice of production steps. These learning forms are not only characterised as a special feature of the acquisition of handicraft skills, similar to the learning of musical instruments, but are also emphasised as a specific feature of the student group.

Just as practise is described as ritualisation, other more structural elements of ritualised procedures are also recognisable. For example, entering the workspace is already seen as a ritual, which leads to a "switch in the mind" of the pupils, as a different form of discipline is required here with regard to work safety. Workflow planning is also used to begin the lesson in a ritualised way and get the pupils engaged in the lesson, and the goals of the next lesson are clarified at the end. This structuring takes places not only through a ritualised lesson plan, but also through visualisations. For example, work plans with photos or pictogrammes are used as prototypes, as well as for clarity.

111 DISCUSSION

According to the teacher beliefs examined in this study, hands-on activity in the context of mental development is a crucial element of technical education. This result is congruent with the "hands-on" orientation of STEM teachers, which Klimaitis and Mullen (2021b, p. 38) have highlighted not specifically for the intellecually disabled, but generally for "students with disabilities". In addition to involving the students, a perceived "increase in performance" was identified as the main reason for this orientation (Klimaitis & Mullen, 2021b, p. 38). The present study results also show that teachers emphasise practical learning as a successful learning strategy, which above all leads to visible and materialised successes of the students and thus promotes self-efficacy. All in all, the teachers interviewed value technical education for its post-school "usability" in everyday life, especially for work- and occupation-related activities. As a vocational perspective, the workshop for disabled adults is particularly emphasised by the teachers. This orientation reflects the theoretical approach behind a work-oriented technical education. The strong craftmanship orientation stands in direct contrast to the increasingly industrial and digitalised manufacturing processes in the work world today. This specific orientation could favour employment in the special system of workshops for disabled adult , although the dismantling of these very workshops is called for.

It is also debatable whether the work-oriented approach contributes sufficiently to pupils’ general technolgical maturity, as the multi-perspective approach to technical education would. Especially in light of the currently heavily technologised world of life and work, a comprehensive technical education is necessary that not only enables individuals to use, produce, and communicate technology, but also to evaluate and dispose of it. In particular, further research on the technologically shaped living environment and its requirements for people with special needs would be desirable in order to contribute to their empowerment.

The work-oriented approach to technical education is also accompanied by a strong emphasis on manufacturing tasks. Other methods of technical education play a subordinate role in the teachers' beliefs. This result is compatible with the findings of Hsu et al. (2011), who found that primary school teachers considered it important to teach design, engineering, and technology, but were relatively unfamiliar with these fields. Teaching related to the production task does include some design elements. Hwang and Taylor (2016) also emphasise opportunities for self-expression for students with disabilities by expanding the concept of STEM courses to include elements of art lessons.

In accordance with the above-mentioned objectives of technical education, a sound subject-related didactic knowledge is necessary for all teachers. Teachers at special schools have comprehensive expertise in tailoring manufacturing tasks to learners' needs. However, they focus exclusively on this method, which mainly involves teaching manufacturing-related, manual skills and work flow planning, and does not cover all competence areas needed for a contemporary technical education. The very fact that almost all teachers in the sample had qualifications in subject didactics testifies to the low practical relevance of the learning content. The content should be oriented towards modern inclusive as well as subject-specific didactic concepts and research results.

The present results are based on a comparatively small sample surveyed in the federal states of Berlin and Brandenburg. A continuation of the research topic in the form of a dissertation written at the University of Potsdam is therefore planned. Furthermore, it would be desirable to initiate research on other topics of inclusive technical education which would contribute to closing the research gap and include the target groups of people with disabilities and all those active in the field.

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Student Teachers' Preconceptions of Programming as a Content in the Subject Technology

Anna Perez Linnaeus University, anna.perez@lnu.se
Maria Svensson, University of Gothenburg, maria.svensson@ped.gu.se
Jonas Hallström, Linköping University, jonas.hallstrom@liu.se

ABSTRACT

In many countries, student teachers are not adequately prepared to teach programming in technology education once they have completed their training. There is a corresponding inadequacy of research regarding pre-service programming education in technology, although in recent years research in this area has increased. There is, however, a lack of research specifically regarding student teachers' preconceptions about programming, which would be important for developing competences needed for teaching in technology. This paper presents a study with the aim of describing student teachers' preconceptions about teaching programming in technology. The study uses a phenomenographic approach investigating eight student teachers' preconceptions after a five-week technology course preparing for primary education, grades 4-6 (teaching pupils aged 10-12). Semi-structured interviews have been conducted with student teachers from two different higher education institutions in Sweden. From the first step of the analysis, three tentative categories have been obtained, describing student teachers' preconceptions as: 1) an understanding of a language and/or a tool, 2) an understanding and use of a language or a tool to solve technological problems, and as 3) a way of understanding and describing a technological environment. The results of the study will contribute with research-based knowledge useful for developing new approaches on how to vary and design the teaching of programming in technology for student teachers to develop skills that are important for their future profession.

Keywords: student teachers, technology education, programming, phenomenography

1. INTRODUCTION

The technology we use today is more digitalised than it has ever been before. Over the last 20 years, our everyday lives have changed and become increasingly digitalised in the form of, for example, lawnmowers, vacuum cleaners, bank transactions, etc. The increased digitalisation of society has contributed to changes in school curriculum documents in Sweden (Skolverket, 2017) and in other countries. In Sweden, digital technology and programming have been included as educational content in, for example, the technology syllabus. Since 2018, teachers in the Swedish compulsory school (pupils aged 7-16) are therefore expected to have acquired the knowledge to teach programming as part of the technology subject. However, many teachers take on this new educational content with uncertainty (Sentance & Csizmadia, 2017; Webb et al., 2017) because the curriculum indicates what pupils should be taught, not how this should be taught or how to address learners' difficulties (Passey, 2017). There is therefore a need for more knowledge about what teaching programming as part of the technology subject entails.

In Sweden, programming has thus not been implemented as its own subject but as part of existing subjects with their established subject-specific content and learning goals. Consequently, teaching activities including programming have to be aligned with existing curriculum intentions (Vinnervik, 2022). The Swedish curriculum in technology involves developing pupils' capabilities to identify and analyse structure and function of existing programmed technology solutions, but also develop their abilities to design new ones and control them with programming (Skolverket, 2017). An important mission for teacher education should be to instil student teachers with the ability to plan, implement and evaluate teaching where such content is processed. Therefore, it is imperative to investigate how student teachers understand their upcoming teaching of programming in the technology subject, after completing their own technology teacher education course.

In many countries, student teachers are not adequately prepared to teach programming in technology education once they have completed their training. There is a corresponding inadequacy of research regarding pre-service programming education in technology, although in recent years research in this area has increased. Yet there is still a lack of research specifically regarding student teachers' knowledge about programming as a content in the subject technology.

112.1 Aim and research question

This paper presents a study with the aim of describing student teachers' preconceptions about teaching programming in technology after completing the technology course in teacher education. The student teachers in this study have not yet had the opportunity to concretize their understanding of teaching programming in classrooms. The following research question is posed:

What are student teachers' preconceptions about teaching programming in technology education?

113 BACKGROUND

Computers and computing were introduced in Swedish schools from the late 1960s, although it took until the 1980s before there was a more concerted effort when the Government pushed the interdisciplinary subject area "datalära" in compulsory school (Nissen & Stenliden, 2023). After several more or less successful attempts at introducing computing and ICT in schools more broadly, the Swedish National Agency of Education included programming in the subjects of technology and mathematics in compulsory school in 2018. As a consequence, a great need for both pre-service and in-service education in programming for mathematics and technology teachers arose, and the Agency subsequently arranged for such courses together with the universities.

There is generally a lack of research about technology teachers and how they conceive of and teach programming, but the little existing research shows that technology teachers feel uncertain about how to teach programming, probably because it has traditionally been a marginal component in technology education e.g., Sentance and Csizmadia (2017); Vinnervik (2022); Webb et al. (2017). Those who taught programming before it was formally included in technology education were mostly computer afficionados that had learnt to program on their own, cf., Nouri et al. (2020).

When primary school curricula documents change, teacher education is also affected, as it has as its mission to educate teachers who can teach according to the current curricula. There is increasing interest in research on the implementation of programming in schools, but so far there has been a lack of didactic research in this area, and in particular research on teacher training. There is some didactic research on students' attitudes and understanding of technology, see for example Lee et al. (2020), but there is a lack of research on students' understanding of the role of programming in relation to the school subject of technology. Moreover, our knowledge of what prospective technology teachers learn about programming in the context of their teacher education programs is very limited. Student teachers' preconceptions about programming as well as what is the nature of programming in technology teacher education, is another under-developed area of research that could potentially shed light on what knowledge components need to be focused on to improve programming teaching in technology (teacher) education.

114 RESEARCH DESIGN

114.1 Phenomenography

The choice of phenomenography as the method for this study is relevant in several ways. Not only is it the world of student teachers and how they experience it that will be investigated (their preconceptions), but the phenomenographic approach is also appropriate because one purpose of phenomenographic studies is to examine the different ways in which teaching can be experienced (Wood, 2000). In phenomenographic studies, a second order perspective is adopted, i.e., descriptions are made of how other people experience different aspects of reality. The focus of phenomenography studies is on a comparison of people's preconceptions of a phenomenon (Marton, 1981) and the phenomena of interest in this study is *teaching programming in technology*. The phenomenographic approach will be used also because it is based on the basic assumption that we humans experience phenomena in partly different ways depending on our previous experiences (Marton & Booth, 1997). That different people may experience the same phenomena in different ways can be explained by the fact that there are differences in what a person's mind discerns. Based on our previous experiences of the phenomenon, what is foregrounded or backgrounded differs from individual to individual (Runesson, 2006). However, there are a limited number of ways to experience the same phenomenon, according to Marton (1981). This study will highlight qualitatively different ways in which student teachers experience or understand *teaching programming in technology*, that is, their preconceptions of this phenomenon. In phenomenographic studies, the area of interest is the collective preconceptions of a phenomenon rather than the individual ones (Booth & Ingerman, 2002; Marton, 1981; Marton & Booth, 1997; Trigwell, 2006). The researcher makes interpretations and describes the preconceptions of the interviewees but it is not of interest who or how many have which preconception but all the preconception are collected in a data set for categorization (Trigwell, 2006).

Phenomenography will be used both as a theoretical approach and as a tool in the analysis process to develop categories of descriptions. The descriptions will be based on the collected preconceptions of the students and will include the aspects that the student's preconception to be salient. The categorization will attempt to show a difference, a variation, that is brought out in the descriptions as the categories are divided by clearly drawing boundaries for when preconceptions are similar enough to be brought together into one category and different enough to be in separate categories. The categories are of interest because they contain the different aspects that students discern of the phenomenon. The categories are also arranged hierarchically so that the categories contain more and less complex preconceptions (Marton, 1981). At the time of data collection, the students have completed their education in technology and therefore it is of interest to see what the students do and do not discern about the phenomenon of teaching programming.

114.2 Data collection

This study builds on a previous study where extensive data was collected using semi-structured interviews and the interview guide was split into two parts. The interview guide included both questions about how the student teachers themselves experience programmed technological artifacts and how they see their future teaching of programming in technology. The latter will be focused for the data analysis in the present study. The student teachers interviewed were eight in number and volunteered to participate in the study in a sample of 30 students from two universities. In the data collection, pictures were used to start the conversation and the pictures depicted four everyday artefacts: dryer, traffic light, keyboard, and elevator. The artefacts have been chosen so that they are familiar to the students but also with the idea that they can be controlled by programming. In addition, these four artefacts can be linked to technical systems, which is an important part of the technology subject in primary schools.

The interview has followed a characteristic phenomenographic structure i.e., the interview guide has been used to support the conversation and the respondent's answers have guided the direction of the conversation. The interviewer's task has been to keep the focus on the phenomenon throughout the interview by repeating the respondent's answers and asking if they would like to elaborate on their answers or add further. Examples of questions that have been asked are "What do you think pupils need to know about programming in technology?", "What is important that we teach them?" and "What is important that you convey to pupils regarding programming in relation to technology?". The interviews were conducted via Zoom with an associated recording function. Each interview has had a time allocation of approximately 45-50 minutes. Each participating student was informed about the aim and design of the study and consented to participate. The responses were anonymised, and data is managed in accordance with the General Data Protection Regulation (GDPR).

114.3 Method of analysis

The analysis will be phenomenographic, which means that the researcher seeks a deeper and more multifaceted understanding of student teachers' preconceptions of the phenomenon in focus, in this case teaching programming in the technology subject. The analysis of the transcripts from the individual interviews began through repeated read-throughs where the researcher, here the first author, delved into the material to find the different preconcepted ways that exist around the phenomenon. This material constitutes a "pool of meaning" which is formed from the researcher first adopting a more open attitude to the material to gradually become more focused (Wood, 2000). Within the "pool of meaning", similarities and differences in preconceptions are then sought to make an initial grouping where it is a matter of trying to discern a variation, or difference, between the respondents' preconceptions. While the first groupings are being made, all three researchers discuss and together question the groupings. Once similarities and differences have been grouped, a description of what constitutes the differences and similarities found between the groups is made to know whether the groups should be merged or new groups created. The goal of the analysis process is to consistently identify the qualitative differences in student teachers' preconceptions when they describe teaching programming in the technology subject.

114.4 Validity of the study

We ensure validity of the data analysis in a number of ways. First, we have chosen to include excerpts of the collected quotes which show answers received in the semi-structured interviews; we have specified the overall questions in the text above, but the follow-up questions have varied depending on the informant's response. In the analysis process, we have also continuously tested the categorisation on fellow researchers. As we are not yet sure that saturation has been reached in our data material, we will continue to collect data.

115 TENTATIVE RESULTS

The analysis yielded a result in the form of categories containing descriptions of students' already existing preconceptions of teaching about programming in the technology subject. In the initial analysis phase, there emerged three tentative categories that are qualitatively different from each other, describing student teachers' preconceptions of teaching programming as: 1) an understanding of a language and/or a tool, 2) an understanding and use of a language or a tool to solve technological problems and as 3) a way of understanding and describing a technological environment.

115.1 Category 1: An understanding of a language and/or a tool

In this category the student teachers describe the use of tools, codes, algorithms as the main purpose of teaching programming in the technology subject. It is the structure of building a code with instructions and consequences of these instructions that are focused. They mention coding activities and practical work with the aim of becoming aware of the instructions. The following quotes from Daniella and Frida illustrate their descriptions of a sense of closeness to the practical aspects:

> Daniella: [...] so how to start it on the computer, how to use these commands, how to twist and turn so you get comfortable using it.

> Frida: It's a lot of following instructions and doing it from the top down and this way, […] for example, you're going to guide your friend and give instructions, or you're going to write down an instruction and then the other person will try to follow it, for example, draw something after the instruction.

115.2 Category 2: An understanding and use of a language or a tool to solve technological problems

In this category student teachers describe the teaching as something that includes the use of programming when solving technological problems. Programming could make things happen and fulfill wishes. Unlike the previous category, programming does not just become a code or a language, but in this category, it is made clear what programming can be used for in relation to the knowledge area of technology. The following quotes from Clara, Daniella and Hanna show a continued interest in practical engagement, while also emphasizing the necessity of problem solving:

> Clara: […] and technology education is largely about, well, how should I put it, identifying needs, and perhaps finding solutions to those needs, and it's quite challenging nowadays to find solutions to needs if you don't have programming skills.

> Daniella: It's not just about coding on the computer, it's something that exists around us, and I can use programming to turn on a light or I necessarily have to use some form of programming if I want to control a lamp or a stove or a dryer. […] But I think that when you program something, it's because it's meant to be some kind of tool, like you want to see something, you want to cook something, you want to dry something. It has a purpose, and that purpose is what belongs to technology. It's not just the fact that it's programmed that makes it technology, but it's what comes after, in a sense.

> Hanna: […] programming in technology is more like we program, for example, [...] carousels, making carousels that make them spin and stuff. It's about making things work, you know. So, in technology, it's like, it's a bit more computer-oriented, in a way.

115.3 Category 3: A way of understanding and describing a technological environment

In this category, the teaching of programming is contextualised as a part of society and thus other aspects than in the previous categories where it was the tools, instructions and practicalities that were in the foreground. Now in this last category, tools and coding are clearly in the background and in the foreground, there is instead a system perspective that has not been visible in previous categories and where programming is instead seen as part of a larger whole, a human-built, technological environment. Björn and Daniella describe this by highlighting several components where they describe teaching that deals with consequences for decisions and actions:

> Björn: To understand that something is happening behind the scenes. There's a reason why the lights turn off in the school corridor when no one has been there. It happens automatically, and it's programmed to do so. [...] Many things can be done to maybe save electricity or save water, and it can also contribute to sustainability thinking. Because I think many students are very concerned about that nowadays. And through technology and programming, there are great opportunities to address those concerns.
>
> Daniella: No, but what I mean is that everything, you learn, it's something that gives you power over your life and how you relate to society. And given that we have a lot more technological gadgets, we also need to have more knowledge about them and how they work so that we can engage with society and its structures. […] So that they can see that programming exists all around, it's in the traffic light when I go to school, what would happen if something went wrong and what would be the effects in a larger context?

116 DISCUSSION

This paper presents a study with the aim of describing student teachers' preconceptions about teaching programming in technology once they have completed the technology course in teacher education but before they implement it in actual classroom settings. From the preliminary results presented above, it appears that there is a variation in how much of everyday life and reality – the human-built environment – the student teachers put into their descriptions. Some talk about teaching code, command, and function with only some everyday connection while others talk about how important it is to have a sense of reality when teaching programming in technology. To better clarify the variation in this study and to achieve saturation in the data material, we plan to conduct focus group interviews with student teachers. An in-depth continuation of this study gives us the opportunity to clarify what the critical aspects can be for teaching programming in technology.

Although the student teachers, in this study may have understood the purpose of the technology subject and how it can be linked to programming, we cannot see that they have sufficient knowledge to be able to teach programming in technology themselves as our results show that only in the last category the students mention conceptions of programming that can be linked to a systems perspective. Teaching with a systems perspective has been shown to be important to increase the understanding of programmed artefacts (Cederqvist, 2020; Perez & Svensson, 2023) and an understanding for the content to be taught is important for future teachers. Critical aspects specific to teaching programming in technology can form the basis for further studies more focused on lesson design.

In summary, the description of student teachers' understanding of programming in technology provides an overview of the knowledge that needs to be developed in student teachers to give them a good foundation for teaching programming in technology.

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Artificial Intelligence Text-to-Image Generation in Art and Design Teacher Education: a Creative Tool or a Hindrance to Future Creativity?

Tore Andre Ringvold, Oslo Metropolitan University, torand@oslomet.no
Ingri Strand, Oslo Metropolitan University, kari-saasen.strand@oslomet.no
Peter Haakonsen, Oslo Metropolitan University, peter.haakonsen@oslomet.no
Kari Saasen Strand, Oslo Metropolitan University, kari-saasen.strand@oslomet.no

ABSTRACT

In today's constantly changing world technological developments in artificial intelligence (AI) can induce educational visions of both utopia and dystopia. New technologies and communication platforms can provide new forms and possibilities of learning. Creating an image has historically mostly been a human process of using knowledge and application of technique that demanded training. This image-making process changed with the invention, development and spread of the photographic camera, when creating a detailed visual representation of reality became a possibility without a complex process of craftsmanship and artistry. The nature of visual art changed but the visualisation of ideas and prefigurative thoughts could not necessarily be captured by a camera. With the development and spread of AI text-to-image generation, can this change the need for competency to visualise ideas in the way the camera changed the need for drawings and paintings as visual representations? This study explores how AI text-to-image generators can contribute to and change art and design teacher education. We conducted exploratory experiments where we tested a variety of AI text-to-image generators and explored the outcome of using different generators, prompts and settings. Reflections were written down throughout the process. This was combined with an online ethnography on text-to-image communities. Different potentials of learning were identified, as well as issues of interaction and possible contexts of use. The results are discussed in a future learning context.

Keywords: Artificial intelligence, Text-to-image generation, Imagination, Art and design teacher education, Visualisation

1. INTRODUCTION

Education and the way we learn adapt to society. Constant changes in technology have led to new cultures and places of learning (Thomas & Brown, 2011). Artificial intelligence (AI) represents new digital technology that has great power to change society. With the rapid development of AI technology, educators need to adapt to emerging technology that can potentially change how we work and produce. Artificial intelligence text-to-image technology has been developed since 2014 and increased in popularity after the introduction of DALL-E in 2021 (Cetinic & She, 2022). In 2022, this development accelerated rapidly with the launch of services such as Midjourney, OpenAI's DALL-E 2, and Stable Diffusion. Since this is such a recent technology, published research on the topic is limited. With the widespread use and rapid technological development, there is a need for research to critically look at the possible use and application of AI text-to-image generation. In this study, we ask: How can AI text-to-image generators contribute to and change art and design teacher education?

118 BACKGROUND

118.1 A short history of visualisation

Prefigurative thinking is seen as an important part of what constitutes being human (Fry, 2012). The prefigurative thought of an idea or concept can be materialised through medium and technique. Doing this and also being good at it are no easy tasks. As most have experienced, it takes time to develop the knowledge and skills to produce traditional visual forms that constitute sensorimotor activities such as drawing and painting. There were no quick-fix methods for creating quality visualisations before the introduction of photography. The process of image creation underwent a significant transformation with the advent, progress, and widespread use of the photographic camera (Gombrich, 1982). It enabled the creation of highly accurate visual depictions of reality without intricate craftsmanship and artistic techniques. However, as prefigurative thoughts cannot necessarily be captured by a camera, there is a need for skills in drawing and illustration (Nielsen, 2013). Can the development and spread of AI text-to-image generation change the need for competencies to visualise ideas in the way the camera changed the need for drawings and paintings as mimetic visual representations?

118.2 Text-to-image generation technology

There are different text-to-image generative systems, but what they have in common is that textual inputs (prompts) are interpreted by a system before images are created. The systems are trained on large datasets of text-and-image pairs from the web (Abdallah & Estevéz, 2023). A prompt can lead to unexpected results, but at the same time the different models, such as Midjourney and OpenAI (DALL-E 2), provide tips on how to alter the style or format by adding specific terms. These tips can help one to affect the outcome and, by adjusting the prompt input, one can increasingly control the image-making process. The images in this paper were mostly created with Midjourney Version 4, which was the default model from November 2022 to May 2023, with Version 5 released on 4 May 2023 (Midjourney, n.d.).

118.3 A changing art and crafts education providing competencies for the future

Norwegian art and design teacher education qualifies students for teaching at all levels, from six-year-old first graders to 18–19-year-old upper secondary school students preparing for work or further studies. In primary and lower secondary school, Art and crafts is a compulsory subject. The 2020 curriculum revision ensures a more future-directed education, in part by making technological use and programming more visible (Norwegian Directorate for Education and Training, 2020). Art and design teachers are also qualified to teach at several upper secondary school programmes, with art, craft and design constituting a central part of their curricula, either specializing in fields such as traditional craft or digital media production. Current pre-service teachers will teach over the next 40 to 50 years, and the extensive development of AI in recent years renders it impossible to predict what the future will look like so far into the future. Rather than transferring knowledge that they in turn will teach, teacher education must prepare students to facilitate future learning processes regarding future challenges.

Artificial intelligence will challenge schools' teaching and assessment practices, and a new government strategy (*Kunnskapsdepartementet*, 2023) requires schools to adopt AI in order to gain a basic understanding of how AI works, its solutions, and its limitations. Thus, teachers and students need sufficient competencies to use AI in an exploratory way, with curiosity, critical thinking, and ethical awareness.

119 METHODOLOGY

We explored AI text-to-image generators over a six-month period from November 2022 to May 2023. We chose a qualitative approach, combining explorative experiments and online ethnography. Dyrssen (2010) states that, while explorative experiments cannot be validated, they allow the researcher(s) to 'shake up ingrained patterns of thought; provide quick feedback, increased curiosity, and discoveries of hidden possibilities; reveal possible links and points that need to be mapped; and get the creative process moving forward' (p. 229).

Each of the four authors tested AI text-to-image generators and explored the outcome of different generators, prompts and settings in use. The authors had little to no experience with AI text-to-image generators and wrote prompts based on their own imagination and curiosities, sometimes choosing to follow interesting idea strands. The combined variety of prompt inputs, ranging from the abstract to the concrete, is reflected in the examples presented in section 4. Throughout the process, reflections were written down and image material saved. Our explorations coincided with significant developments of the generators, such as the release of Midjourney Version 5.1 and solutions to recurring issues such as the depiction of fingers (Verma, 2023). Due to the rapid development, we are more concerned with the overarching concept of AI text-to-image generators than specific technical aspects.

The authors shared their experiences in frequent meetings, drawing on their own backgrounds in design and education. Each author has approximately 10 years of teaching experience covering all levels, ranging from Year 4 (nine-year-olds) to university level. Through reflective dialogue, we discovered central issues regarding our experiences of AI text-to-image generators, as well as staking out a path for further experiments. The first author also conducted an online ethnography (Hart, 2017; Winter & Lavis, 2020) in the text-to-image community of the Midjourney server on Discord, capturing users' interactions at three different timepoints.

Through a thematic analysis (Braun & Clarke, 2022) of the empirical material from the explorative experiments and the online ethnography, we discovered themes related to AI text-to-image generators' potential for learning, limitations, and hindrances, as well as issues of interaction and possible contexts of use. The results from this analysis are presented and discussed in the following section.

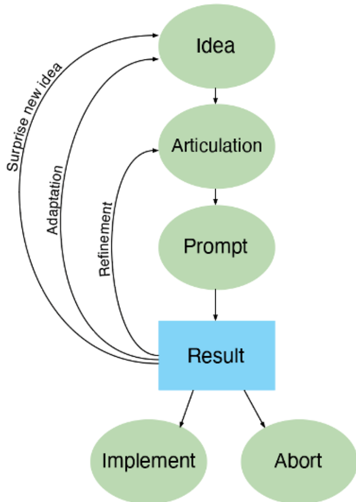
120 A TEACHER TRAINING LEARNING PERSPECTIVE ON AI TEXT-TO-IMAGE TECHNOLOGY

The results and discussion are presented in a bilateral manner of learning potentials on the one side and learning obstacles on the other. However, the identified qualities are not necessarily either a potential or a hindrance to learning; they can be both at the same time.

120.1 Modes of creation processes from a learning perspective

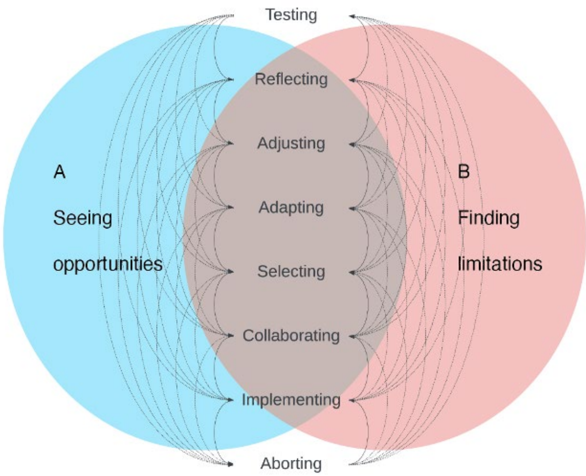
Creating visualisations using text-to-image generators is a cyclic, iterative process. We identified this image creation process as consisting of several stages, as visually presented in Figure 1. The first of these is the idea stage. This can be a prefigurative thought at the beginning of a process, the refinement of previous ideas, an adaptation of a previous idea, or a surprising new idea that originated from a previous process. Taking the step from idea to a written prompt, one needs to shape the visual idea or concept through articulation (stage 2). After feeding the prompt in writing (stage 3), a black box process (Bunge, 1963) gives one the results (stage 4). Results can be implemented (used) or aborted (left unused). They can also be refined, adapted, or used to start new ideas in a cyclic process.

Figure 38.
The identified image creation process using AI text-to-image generation.



In addition, we propose an understanding of the learning process that takes place while using AI text-to-image technology (Figure 2). In a cyclic, interactive learning process between the human user and text-to-image AI technology, a variety of actions can take place in an interchange between A: Seeing opportunities and B: Finding limitations. These actions can contribute to the cyclic development of learning processes of varying length. Variations also apply to the actions involved in the cycle.

Figure 39.
A proposed representation of the cyclic human user and AI text-to-image interactive learning process.



120.2 4.2. Potential learning opportunities

120.2.1 Play with imagination: A training exercise in prefigurative thinking?

Artificial intelligence text-to-image technology provides the user with a powerful tool to generate visualisations without much effort. This ease of access to visualising allows for playful image-making. The image creation could, especially at the beginning of using the technology, be about testing limits and seeing what is possible, as illustrated in Figure 3. Using this technology, students can possibly push their own boundaries of imagination. The ease of access can trigger a willingness to try and experiment with creative image making. Early adolescents may experience a more critical view of their produced drawings, as described by Lowenfeld (1947). For the non-professional image creator, text-to-image generation can provide a beneficial training ground and a tool for visualising, both mentally and physically. This is especially relevant for those who are hesitant to enter the creative processes of image making.

Figure 40.
Novelty wow factor tests created with Midjourney (V4). Prompt 1 (to the left): Unimaginable thoughts happy extreme. Prompt 2 (to the right): A muppet riding a centaur galloping along a windy beach.

120.2.2 An online arena for sharing and collaborative creativity

Midjourney and Discord provide an arena for knowledge-sharing and collaborative generative art and design processes. These processes take place via a variety of chatrooms, show-and-tell rooms and other channels of communication. In these multi-human and machine collaborations, several users and the AI generative technology are part of discussions. Through discussions and testing, they collaborate on developing prompts, aesthetic qualities and designs. This online space for potential collaboration and co-learning provides a learning environment independent of place. Figures 4.1, 4.2, 4.3 and 4.4 provide examples of Midjourney users collaborating and helping each other to achieve a desired image. Collaboration and seeking guidance from others through sharing is an important part of creative professional work and are also highlighted in new curricula in primary and secondary education (Norwegian Directorate for Education and Training, 2020).

Figure 41.1.
Attempting a human-like Marge Simpson through prompting. Chat conversation, requesting prompt help. Discord, Midjourney server, prompt-chat screenshot.

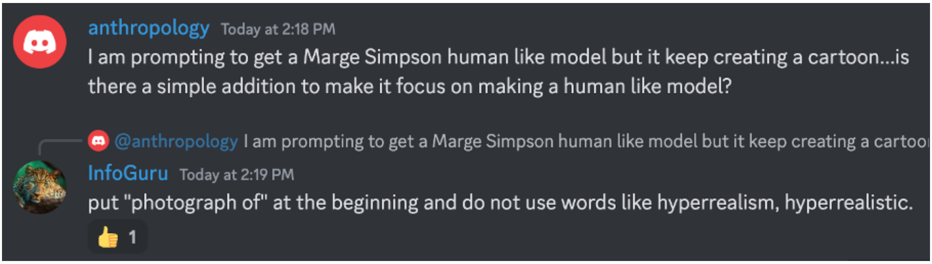


Figure 4.2.
Help suggested. Discord, Midjourney server, prompt-chat screenshot.

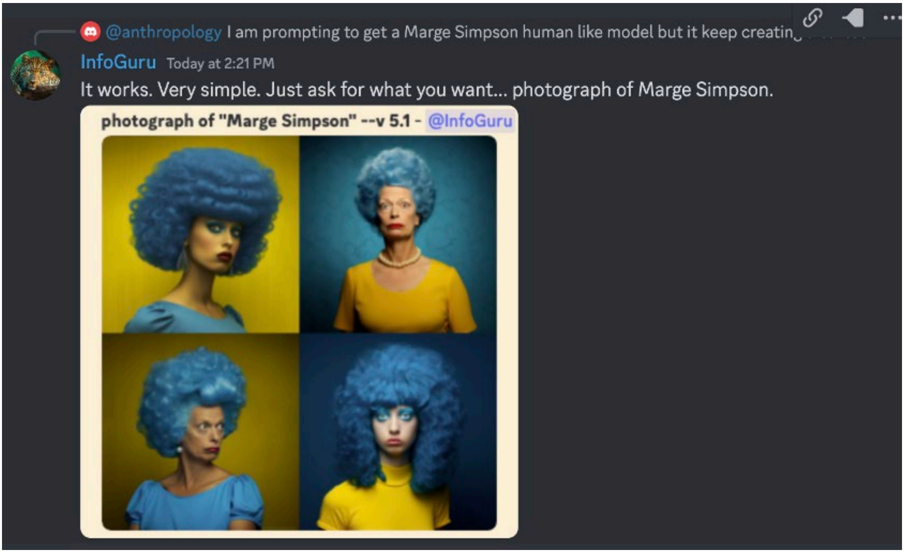
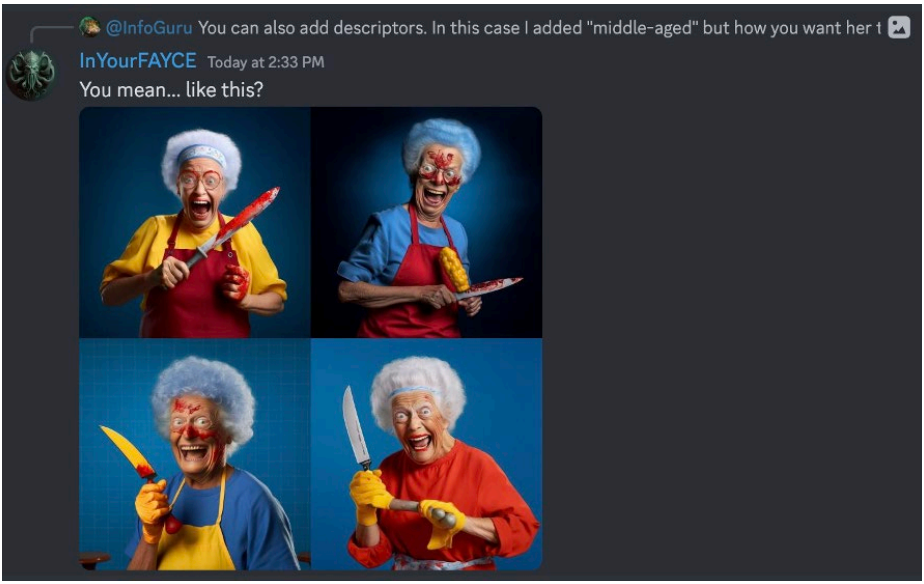


Figure 4.3.
Help suggested, follow-up. Discord, Midjourney server, prompt-chat screenshot.

Figure 4.4.
A third user joins the discussion with a comment and showing their own take on the prompt. Discord, Midjourney server, prompt-chat screenshot.



120.2.3 A visual aid for developing perspectives and composition

Artificial intelligence images can be useful visual aids for creative work. In our exploration, one of the authors tried this approach to draw compositions for a comic book, including an image of a large dragon sleeping in a parking house. Using AI, he could explore how to draw this composition. Images created with Midjourney often do not meet the creator's expectations, but the images can be used as sublayers for reference in constructing illustrations. By prompting several iterations of a dragon and the environment and combining multiple images to get a reliable perspective (Figure 5), the drawing could be completed.

Figure 42.
Dragon and environment image generations combined with author's own sketch work (far right), used for reference in creation process.

120.2.4 A multitude of idea generations

The study identified that, in creating object designs, the AI generated a multitude of varying idea visualisations. A series of relevant designs were easily created when the object shape was conventional, such as a ring (Figure 6), or a conventional design such as a car or a toaster (Figure 7). The AI does not rethink a functional need or type of use but generates imagery based on convention. This does not mean that all suggestions are conventional. Mashups of existing design visualisations can provide interesting results or suggestions useful for further exploration. The variations are more decorative rather than shape variations. In a creative learning process, students' abilities to generate ideas differ. A common obstacle in the creative process can be a lack of variation of ideas in the early stages, leading to unsatisfactory results that do not fulfil their potential. The ease of generating idea visualisations can help prevent concept or design fixation (Schut et al., 2020). Artificial intelligence text-to-image technology can provide new avenues for solutions to a problem or new ways of seeing and understanding.

Figure 43.
Different engineering department alumni ring design propositions created using Midjourney (V4). Prompts: An engineering signet ring 21st century, construction computing, and mathematical.

Figure 44.
Different toaster design propositions created using Midjourney (V5). Prompts: A toaster made of delicate porcelain, sheer origami paper, mosaic.

120.2.5 Potluck visualisation as a tool for creativity

Artificial intelligence text-to-image generation can be a game of chance, providing surprising image results. This potential potluck quality of AI text-to-image generations led us to look at our initial ideas in new and unforeseen ways. Opening new avenues of thought can be rewarding in the creative process. While providing new possibilities, it also emphasises the need for a more critical creator role, as described in section 4.2.7. Using chance or coincidence in idea generation can contribute to new perspectives that enrich the creative process (Fazel & Almousa, 2021). Surprising image results, unrelated to the original idea, can be exciting to develop further. In these cases, the process, or 'dialogue' with the text-to-image generator, produces new and unexpected outcomes. This resonates with Oppenlaender (2022, p. 198), who has referred to unexpected results and serendipity.

120.2.6 Developing and strengthening a visual reference language

We identified articulation as an important stage between idea and prompting (Figure 1). The training of articulation from prefigurative thought to writing can contribute to the development and strengthening of a visual reference language. On the one hand, the ability to use the subjects' terminology is often highlighted in curricula. On the other hand, when articulating and writing prompts, one might use words or phrases not necessarily viewed as correct in the art and design discipline. However, they work well when prompting due to their widespread use online, for example in gaming communities.

120.2.7 The 'concept-articulating catalyst wizard', a changing role of the image creator?

The study's exploration identified that the role of creator in creative processes using AI text-to-image technology differs from the creator's role in traditional image making such as drawing. We see the creator's role shifting towards that of an art director, composer, editor, or selector. The process role of editing and catalysing black box processes (Oppenlaender, 2022; Vartiainen & Tedre, 2023) consists of articulating, testing, developing, adapting, refining, selecting and editing by starting new cyclic processes, as described in Figures 1 and 2. This shift in the creator's role questions what kind of knowledge and skills will be needed in future creative processes. With a shift towards editing and selecting rather than producing, a critical mindset should be an important part of future creator and design competencies. Such a mindset should be critical of results and open to different solutions of visualising prefigurative thoughts.

120.3 Potential learning obstacles

120.3.1 Chasing the centaur, not getting what one wants

An example from our testing was to create a centaur by using different prompt-writing approaches. Whether writing a short prompt, such as 'centaur', or describing what a centaur is, the results were mainly images of horses. Other results depicted a man standing in front of a horse-like body, or a human torso attached to a horse's back. Although other Discord users in the Midjourney community had managed to create centaurs, a successful prompt copied and pasted from the community also elicited poor results. Other absurd combinations were also difficult to accomplish. The first attempts at creating AI images may be fascinating, but the wow factor will not necessarily last for long. Trying to create something based on ideas and imagination may lead to disappointing results that do not match how one visualised the ideas in the first place. The natural limitations of a given technology or tool will limit the possibilities.

120.3.2 Ethics, copyright and censorship

Who owns images created with AI? Being trained on large datasets from the internet, there is no guarantee that images will not violate any copyrights (Abdallah & Estévez, 2023). In a classroom setting one can explore and experiment with images without violating copyrights (Bergman, 2021). However, as Midjourney shares the generated images with the community and the creator alike, one can question which copyrights are potentially violated with each image generation. Making images in an AI-based process provides a natural ground for discussing ethical dilemmas of copyright infringements and obstacles of censorship. Due to different types of censorship, some of the AI models have certain constraints. With Midjourney, one cannot create imagery based on prompts that suggest sexual content, while materials potentially violating copyright or personal data issues seem to be accepted. Compared to Midjourney (Figure 7), the new beta version of Adobe Firefly seems more restrictive. These limitations in technology due to censorship, copyright or privacy issues limit the user's freedom to express their prefigurative thoughts in visualisations.

Figure 45.
A comparison of two different providers with the same prompt, Realistic photo Mickey Mouse portrait. Left: Midjourney V5. Right: Adobe Firefly (beta).

120.3.3 Bias and stereotypes

As the images generated by text prompts are based on image-and-text pairs from the internet, biases and stereotypes may be reproduced (Vartiainen & Tedre, 2023). If ethnicity or gender is not specified in a prompt, a white male is often featured in the results, unless the prompt describes people not associated with men, for example, a nun or a geisha. In an attempt to create images of a female adult piano player, Midjourney generated images of skinny young women and girls, although the prompt contained words such as '40-year-old', '50-year-old', and 'middle-aged'. Finally, after asking for a 'geriatric' woman, the results did not include young girls.

120.3.4 A cop-out?

The low-effort ease of image making with AI makes us question whether its extensive use can result in a non-critical view on the benefits of making. If the use of AI text-to-image technology replaces sensorimotor making activities such as drawing, what is possibly lost in a creation process consisting less of producing and more of articulating and selecting? In traditional image-making processes consisting of applying sensorimotor techniques, training is essential. Drawing skills are developed over multiple years of practice. If such sensorimotor skills for producing imagery based on prefigurative thinking become superfluous, what is the incentive in education to develop sensorimotor skills for mimetic drawing, as described by Nielsen (2013)? Is this ease of use a hindrance to learning or can it possibly free up more time to focus on other knowledges and skills necessary in a future learning environment? The use of AI technology in learning processes demands a critical teaching mindset, ensuring the necessary training and development of the skills needed.

121 CONCLUDING REMARKS

Artificial intelligence text-to-image technology can contribute to and change future art and design education in various ways. It can contribute to increased opportunities for training prefigurative thinking, providing new ways of visualising and co-creating. This can represent a democratization of visualising prefigurative thinking, as creators are not being restricted by their limitations in skills or techniques. The use of AI can simplify and enrich image making and design processes. Artificial intelligence text-to-image technology can represent a useful tool for creative processes and developing articulation for visualising the imaginary. Its use can also represent limitations to creativity and contribute to ethical questions and issues of bias being raised. With the application and use of AI text-to-image technology in art and design education spreading, we need to question what kinds of competencies are needed in future learning processes.

This limited study has identified several possible avenues for further research. With the widespread use and development of this technology, we emphasize the need for a critical perspective in future research.

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Tackling Food Poverty: the Role and Importance of Food Education in United Kingdom Schools

Marion Rutland, University of Roehampton, m.rutland@roehampton.ac.uk
Ruth Seabrook, University of Roehampton, ruth.seabrook@roehampton.ac.uk

ABSTRACT

This paper explores the role of food education in helping tacking food poverty in United Kingdom (UK) schools. Currently, more children in the United Kingdom are experiencing food poverty, impacted by the Covid pandemic and the rising cost of living crisis. Food poverty can have a significant impact on social mobility, educational attainment, and long-term health issues. This paper discusses and reflects on how food education in schools can help tackle food poverty through Design and Technology (D&T) and the concept of designing and making with food. This is because, it includes the development of knowledge, understanding and skills involved in the practical preparation of food, alongside the application of investigative and experimental activities. It is important to understand that food education in the classroom is much broader than just 'teaching children how to cook.' When children are handling food, they need to know and understand how, why, and what they are doing. This includes the development and creative design of food products and the knowledge related to food preparation, nutrition together with an understanding of the reasons underlying the specific choices of ingredient and food in their diet. In the classroom children need to be exposed to a curriculum and pedagogy that provides a pathway into their future lives as healthy adults in a multicultural world, considering issues such as where foods come from, food availability, the environment and sustainability. Food provides a pathway and progression for children into a career in the hospitality and food industry, teaching and activities that require an understanding of the issues and basic scientific and technological principles involved in food preparation and its relationship with a healthy body. The many food-related courses availability in further and higher education will further broaden and expand this knowledge and understanding necessary for working in the 21st Century food industry.

Keywords (food poverty, children, food education, D&T, schools, curriculum)

1. INTRODUCTION.

The initial idea for authoring this paper came from the chapter Food Poverty and how it affects United Kingdom (UK) children in the long term. (Seabrook, Rutland, 2003) in the book Food Futures in Education and Society (Sing Lalli, Turner, Rutland, 2024). It explored and evaluated the fact that more children in the United Kingdom (UK) are experiencing food poverty. Past UK government approaches to food poverty, up to and including the impact of the Covid pandemic and current cost of living crisis were reviewed. It concluded that food poverty can have a significant impact on social mobility, educational attainment, and long-term health issues,

It was argued that food poverty means that children have access to lower quality and a restricted range of foods and often go hungry, with their only access to food via free school meals (FSM) vouchers. Teachers regularly report that pupils are fatigued, have poor concentration and are regularly ill, due to poor nutrition and hunger. Children who get FSM are less likely to get A* - C grade at General Certificate of Secondary Education (GCSE) then wealthier peers (Children's Society, 2022). Food security on the other hand is where an individual is considered food secure when they can access sufficient, safe, and nutritious food always to maintain an active and healthy lifestyle. (Food and Agriculture Organisation (FAO), 2006).

This thinking highlights the importance of food education in schools in that it helps create communities and social cohesion and the benefits go way beyond its nutritional value as is brings people together, combats poor mental health, fights loneliness, and increases self-worth and esteem' (Fareshare, 2022). There has always been hunger and poverty in the world but as societies have grown and become prosperous, there is a perception that the majority live securely and have access to the basic necessities. Yet, millions of people are currently struggling to get by with the poorest of living standards. Around 14 million people are living in poverty in the UK; eight million are of working age, four million are children and two million are retired (Joseph Rowntree Foundation (JRF), 2020).

In the State of Hunger Report (The Trussell Trust, 2021) it was found that those people more susceptible to food insecurity were higher in lower income households, the unemployed, younger age groups, single parents, social housing renters and those with disabilities or ill health. This situation is not improving as shown by more recent figures. Between 1 April 2022 and 31 March 2023, food banks in The Trussell Trust's (2023) UK wide network distributed close to 3 million emergency food parcels to people facing hardship and this is an increase of 37% from the same period last year. More than one million of these parcels were distributed for children.

This paper considers the role and importance of food education in UK schools, an issue that can be traced back to the 1840s when basic training in cooking and domestic economy was introduced to prepare girls for low paid employment and domestic life (Rutland and Owen-Jackson, 2015). The reasons underlying current concerns over food education in schools were, as in the 1840s social and political and relate to the health of the nation (Geen et al., 1988: 8).

So why are the issues of food poverty and food education so relevant and important in schools today? The cost of living has been rising in the UK and across the world. Food and energy prices have been rising markedly over 2022-2023, particularly gas prices, in response to the conflict in Ukraine and global recovery from the coronavirus (COVID-19) pandemic. Food education in schools has a significant role to play in addressing these issues for our children today and in their future lives.

In the UK, the price of consumer goods and services rose at the fastest rate in four decades in the year up to October 2022. The annual inflation rate dropped slightly from 9.2% to 8.9% between

February and March 2023 but was still high compared with recent years. The prices of food and non-alcoholic drinks rose at the fastest rate in more than 45 years in the 12 months to March 2023. Cucumbers (up 52%), olive oil (up 49%) and hard cheese (up 44%) but was still high compared with recent years. The largest contributor to the rise in food inflation was bread and cereals, for which the average prices rose by 19.4% in the year to March 2023 (Office for National Statistics, 2023).

123 METHODOLOGY

This paper adopts a qualitative approach, based on desktop research and empirical research with observations drawn from experience rather than from theory or belief. It considers and takes note of historical, socio-economic, political, educational, and contemporary issues of child food poverty in the United Kingdom. The literature is drawn from journal articles, report findings and expert opinion from charitable bodies, who collectively work in unison to address child food poverty and the inevitable health inequalities that need to be corrected.

124 DISCUSSION

In many countries, with increasing concerns over health, food education sometimes known as *food literacy,* or understanding the impact of your food choices on your health, environment, and economy – and that these impacts are not experienced equitably (Food Literacy Center, 2023) has become an important part of pupils' education. Aspects of food education such as nutrition may also be taught in science, physical education or personal, social, health and economic education (PSHEE) as well as currently in England within Design and Technology.

However, food education has overall a wide remit; in schools there is a need for a robust, theoretical framing, e.g., socio-cultural; scientific theory (food science); technological understanding, environmental issues, product design, nutritional knowledge and cooking skills that is taught in an experimental, sequential, and integrated approach.

Overall, pupils' practical capability in food preparation and understanding is enriched if they also develop technical knowledge and skills related to nutrition, food science and food product development, as well as decision making, analytic and evaluative skills. Food education, as found in Design and Technology in England provides pathways and progression through the school curriculum and beyond, into tertiary and higher education, research, the food industry, and other food related employment. (Rutland, Turner, 2021).

124.1 The impact of heavily processed foods on our diet.

It is important to appreciate, that not all children today will learn how to cook in the home, though this may have been true in the past and still will be the case in some countries. Due to changes in lifestyle and roles many societies have seen a reduction in the time spent preparing food in the home. The food industry is an increasing powerful and prosperous sector across the world, and people increasingly rely on heavily processed, factory produced food products that are easy to buy, store and quick to prepare. These foods take less preparation time, are less nutritious due to the increased use of food additives, though relatively inexpensive against using fresh ingredients.

As a nation 50% of UK household food purchases are ultra-processed (UPF). The food industry is responsible for producing highly refined, cheap foods and this has a significant impact on our diets as many of these foods contain additives, preservatives, and antifungal agents to extend the shelf-life. These foods can be separated into four categories depending on how much they have been processed during their production: unprocessed or minimal processed; processed culinary ingredients, processed foods and UPFs. Unprocessed foods include fruit, vegetables, eggs, meat and grains, UPF typically have five or more ingredients and contain industrial substances such as preservatives, emulsifiers, sweeteners, and artificial colours and flavours. Examples of ultra-processed foods include ice cream, ham, sausages, crisps, mass-produced bread, breakfast cereals, biscuits, carbonated drinks, fruit-flavoured yogurts, instant soups, and some alcoholic drinks including whisky, gin, and rum (BHF 2023).

Two landmark studies have recently revealed that ultra-processed food significantly increases the risk of high blood pressure, heart attacks and strokes. Even "healthy" processed options, such as protein bars, breakfast cereals, low-fat yoghurts and supermarket sliced bread are linked to worse heart health. The findings presented at the European Society of Cardiology Congress (2023) in Amsterdam, call for ultra-processed food to be treated like tobacco and say regulations must be in place to restrict advertising and the sale of such products.

In addition, it is currently projected by 2035 there will be more spent on Type 2 Diabetes than we are currently spending on all cancer treatments. However, some mandatory interventions have had important levels of impact, over a brief period. In an independent review by the government, the National Food Strategy, (DEFRA, 2021), the UK's soft drinks industry levy (Institute for Government, 2023) has led to a 29% reduction in the average sugar content of soft drinks within three years.

124.2 The importance of food education.

There are countries and populations, such as the UK where people rely on *food banks* and other charity-based organisations to feed their families.

These issues highlight that good food education in the classroom is particularly important, but that it will be dependent on the local environment and the expectations and requirements of a society, the culture of the area surrounding the school and the people that live there. All these aspects need to be considered when planning children's food education in the classroom and are essential to prepare and education them for their future lives.

Food education in the classroom is much broader than just 'teaching children how to cook.' When they are handling food, they need to know and understand how, why, and what they are doing. Food education includes the designing and making of creative food products, combining all the skills and knowledge related to food preparation and nutrition and not just based on following a recipe. It would be unwise to leave this to out-of-school clubs or side-line it into less important and less valued elements of the school curriculum.

In the classroom children need to be exposed to a curriculum and pedagogy that provides a pathway into their future lives as healthy adults in a multicultural world, considering issues such as where foods come from, food availability, the environment and sustainability. Food education lessons in schools provide a pathway and progression for children who want to follow a career in the hospitality and food industry, teaching and a range of other careers and activities that require an understanding of the issues involved in food and its relationship to a healthy body. The many food-related courses in further and higher education will broaden and expand the basic scientific and technological aspects of food taught in schools. Food education in schools should ensure that children are fully prepared and informed for their future, healthy lives in the 21st century.

124.3 Key issues in food education and a way forward.

Since the late 1990s there have been some fundamental changes to the teaching of the subject of D&T overall, but more significantly in respect of the teaching of food and the methodology used in the teaching of the subject. Initially, there was a compulsion for every pupil in England to sit a Technology subject at GCSE and food technology was an extremely popular choice, although more so by girls than boys (Owen-Jackson 2013 p106). Provision included GCSE Food Technology for pupils aged 16 and Advanced (A) Level Food Technology for pupils aged 18. These overall provided a pathway into higher education for pupils interested in following food related courses and the food industry and they remained in place until 2016/2017.

The introduction of a new National Curriculum for D&T meant that all GCSE and A Level D&T subjects (DfE, 2014) were reformed and it was decided to develop a combined GCSE Cooking and Nutrition, with a name change later to GCSE Food Preparation and Nutrition (DfE, 2015). The new qualifications focused on ensuring students acquire a good understanding of food and nutrition together with excellent cooking skills (ibid: pp. 6-7). A new Food Technology A level course, providing a pathway for pupils aged 18 years and progression to higher education courses, was not developed for schools as it was considered that there was several high quality vocational qualifications such as confectionary and butchery available (DfEa, 2014).

Further influences and changes since then have includes Academies (groups of schools) adopting their own food education curricula, new food teaching standards for both primary and secondary, the commission of the *FELL Report* (Oliver, 2017), the *National Food Strategy* (DEFRA, 2021), the governments *School Food Standards Guide* (DfE, 2023) and more recently the *Food Education: fit for the Future* by the Food Teachers Centre (Davies, Ballam, 2023). Despite all these pupils still seem to have limited practical cooking opportunities and there is little focus on pupils' values, aspirations, and motivation to make healthy food choices. (Oliver, 2017)

In reality, pupils study 'core' academic subjects and are now given far fewer options of other GCSE level courses. All the remaining creative subjects are together in one or two option blocks, allowing little choice for pupils (Turner, 2017). It was suggested that the likelihood of this move was that the arts, technology, physical education, and religious studies would be lost to accommodate compulsory history and geography (SSAT, 2015). The government's ambition appears to see 90% of GCSE pupils choosing the EBacc subject combination by 2025 (DFE, 2019) and this will surely have a further on ongoing impact for the uptake of D&T, including food in the coming years.

If we look at the national figures for Food Technology GCSE entries since 2013 – 2017 (DATA, 2017), we can see that there was a steady decline in the number of uptakes of the subject area from 44,642 in 2013 to 29,773 in 2017. This is a percentage drop of 33.31%, which is alarming to say the least.

The Food Teachers Centre Report (Davies, Ballam, 2023) noted that only 23% of those respondents (teachers) offering any Post 16 vocational courses and out of 306 responses 93% felt there was not sufficient post 16 level choices available. Some of the options available include WJEC level 3 Food Science and Nutrition (being the most available) but others include Hospitality, Leith's Professional Cookery Level 3, International Baccalaureate (IB) Food Science and Technology and Business & Technology Education Council (BTEC) Home Cooking Skills. The outcome of any future review should include more practical based, comprehensive, and more academically recognised options for pupils at a post 16 level.

An additional impact on food teaching includes the time allocation for lessons. *'When lessons are only fifty-five minutes long, there is little time for practical of any great skill, importance and scientifically nutritionally sound '(Teacher D, Seabrook, 2018a).*

> 'In my first school food teaching reduced to one hour per week. This was then reduced to fifty minutes, a nightmare for food teaching' (Seabrook, 2018b)

Results from a National Questionnaire (Seabrook, 2018a) indicated responses of 22% saying that their school no longer had food in the curriculum at all, which is a disappointing statistic. The reasons pertaining to this were the lack of facilities, resources, and schools' inability to find well trained food specialist teachers coming through into education. The total number of D&T Early Career Teachers in England is up slightly from 334 in 2021/22 to 450 in 22/23. However, this is against a target of 1,825, which is only 25%, and this figure includes all D&T, Food and Engineering courses. This indicates not only how few D&T teachers were recruited, but more importantly how few were food specialists. There are no breakdown figures available from the Initial Teacher Training Census 22/23 (DfE, 2023).

125 CONCLUSIONS AND RECOMMEDATIONS.

Today school food education is varied in both quality and quantity and depends, on how important schools' Senior Leadership Teams view it. The *Report of the Food Education Learning Landscape* by the Jamie Oliver Foundation (Oliver, 2017) noted many concerns. These included that pupil's knowledge of healthy eating was incomplete, the delivery of all aspects of food education was patchy and many children were unable to develop their cooking skills. There was also limited evidence of pupils being taught how to apply the principles of a healthy diet in their food choices. Teachers are often held back by a lack of time, resources, and facilities with insufficient professional development to improve these skills.

There is further evidence from the Report (DATA, 2017 p44) that for curriculum-based food education to have a maximum impact; it needs embedding within the wider school food culture. Although many schools adopt a whole school approach to food education and there is support provided by a positive food culture and environment, this unfortunately is not the norm in all schools. Schools need to prioritise food education and provide robust continuing professional development (CPD) for teachers, to enhance their knowledge and understanding about topics such as food poverty and security, production methods and sustainability.

There is an urgent need to revise the current GCSE Food and Nutrition examination to enable the development of an A Level examination in food that will provide progression to further and high education food related courses. Such courses will provide suitably skilled and qualified people able to enter the food industry to ensure the qualities required in food products to ensure health and protection against the development of food poverty in our children and the future population. The development of food within the Design and Technology curriculum in England across the full age range of 11-18 years can ensure this will happen. It will not only develop children's 'cooking skills', but it will have a much wider impact on developing important food related knowledge, understanding and skills required for our children's future health and their ability to follow a wide range of food related career opportunities.

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Technology Education Considering Children's Needs: Evidence-based Development of Inclusive Materials for Learning with Robots at Primary Level

Franz Schröer, University of Paderborn, franz.schroeer@uni-paderborn.de
Claudia Tenberge, University of Paderborn, claudia.tenberge@uni-paderborn.de

ABSTRACT

The developmental task inclusion effects the design of teaching and learning regarding technology education at primary level. National studies have addressed the issue and have devoted efforts to theory-based development of conditions for inclusive education and their empirical substantiation (Schröer & Tenberge 2022). In German primary schools the subject 'Sachunterricht' includes among other domains technology education. An essential field of research is shaping the developmental task inclusion in the context of technology education. However, narrowing down the concept of inclusive education for the multiperspective school subject 'Sachunterricht' is complex (Seitz 2018). The use of potentials and consideration of individual needs is one distinguishable context when conceptualizing inclusive education in 'Sachunterricht'. The consideration of needs in classrooms can be substantiated based on the theory of basic needs (Krapp 2005). Research demonstrates that problemsolving activities with varying degrees of self-direction take different needs into account (Beinbrech 2003; Tenberge 2002). However, the design and substantiation of learning settings, that regard to pupils needs, have so far been largely omitted by research. This justifies the idea of the presented research project. Based on the theory of basic needs, rooted in developmental psychology (Ryan & Deci 2018), a set of problems and tasks for problemsolving with the learning robot Bluebot™ was developed. Learning settings were tested in classrooms and evaluated in a first cycle to adapt them based on evidence. Preliminary findings of pre-post comparisons show effects on problemsolving skills and self-efficacy. The present article falls into four sections of which the first one will define the fundamental concepts addressed. After substantiating the requirements of inclusive technology education, section two will introduce the adaptive set of tasks for technological problemsolving at primary level. Based on the methodical framework in section three, findings from the first cycle of a design-based-research project are presented and discussed.

Keywords: Technological Problem Solving, Inclusion, basic needs, learning robots

1. INITIAL SITUATION

In a world permeated by technological artifacts, problems, processes, and values, capabilities related to the use, construction, invention, and disposal of technology are fundamental for responsible participation. Under the assumption of a constructivist approach to teaching and learning (Möller, 2012) the objective of technological literacy has been adopted in educational systems all over Europe (De Vries, 2018). Therefore, technological literacy shapes the nature of learning objectives, contents, and methods.

Considering, the idea of an inclusive educational system, conceptions, methods of inquiry, and goals of technology education have to be reconsidered in modified circumstances (Schröer & Tenberge, 2023). School subject related research for education at primary level in Germany has taken up the issue and devoted some effort into the development and redesign of teaching and learning under inclusive requirements.

1.1. Theoretical Framework - Technology Education at Primary Level in the German educational system

Unlike in many other countries technology education at primary level in Germany is integrated in one school subject along with scientific and social scientific education called 'Sachunterricht'. Since the common translation into 'interdisciplinary science and social studies in primary education' does not mention the technology education part of the subject, the German term is adopted for a precise description of what is meant in the present article.

One fundamental idea of 'Sachunterricht' is to stimulate children's learning about their environment from a variety of different perspectives of which a technological perspective is one. This principle is addressed to as multi-perspectivity (Thomas, 2015). It implies that one can learn about an artifact or a phenomenon from various perspectives. The perspectives addressed in teaching and learning arrangements are then iteratively related to different areas of inquiry and bodies of knowledge (Köhnlein, 2012). Following this argument, the coexisting conceptions of 'Sachunterricht' are shaped by three fundamental categories.

- ***(i)*** Children with their different preconceptions, interests, ideas, questions, and needs (Fölling-Albers, 2015)
- ***(ii)*** Living Environment with the areas in which children act, which they explore and in which they have experiences (Nießeler, 2015)
- ***(iii)*** (scientific) domains with their bodies of knowledge, methods, and processes of inquiry as well as the nature of science and technology (Köhnlein, 2015)

Accordingly, Technology can be thought of as a scientific domain as well as a section of one's living environment. Regarding children as a determinant to the design of teaching and learning, Mammes (2001) states that children are often interested in how technological artifacts are constructed, used, or disposed. Referring to Erikson (2003), Tenberge (2002) ascribes a kind of sense to create to children, especially those of young age. Therefore, several theoretical approaches to principles of technology education at primary level emphasize a combination of hands-on and minds-on learning activities as a productive way to explore technology (Möller, 2015).

1.2. Learning objectives

As mentioned in the outline, the main goal of technology education at primary level is to enable students to participate in a society that is permeated by technology.

Based on hands-on and minds-on learning activities, fundamental sections of learning objectives under the literacy theorem are the analysis of technological functions, the understanding of the impacts of technology, the communication of technology and the comprehension of connections between technology, economy, and science (Möller, 2021).

1.3. Contents

The identification of relevant and enduring content for technology education at primary level becomes more complex under the conditions of an increasingly complex and inscrutable nature of technology and fast development of technological innovations.

Federal states in Germany have revised their policy curricula in recent years and often included content elements linked to requirements of digital technologies in children's learning environment. The binding curriculum for the federal state of Northrine-Westphalia added the simulation and description of the principle of input, processing, and output to the contents for 'Sachunterricht' (MSB NRW, 2021). The media literacy framework established through federal policy emphasizes the identification, understanding and reflection of algorithmic patterns in different contexts as an area of learning at primary level (MSB NRW, 2020).

Subject related research as a distinguishable area from educational policy does as well formulate and substantiate content areas for technology education. The predominant focusses here are on the stability technical structures, the functionality of tools and machinery, the construction, functioning and propulsion of vehicles, the utilization of natural forces and finally the comprehension of important inventions of mankind (Möller, 2021).

1.4. Methods

Unlike the natural sciences with their causally oriented mode of inquiry, technology is characterised by a final orientation (Möller, 1998, 2021). Therefore, methods of technology education relate scientific laws on the one hand to the social side of technology on the other (Mitcham, 1994; Ropohl, 2009). Technological problemsolving uses this principle of inquiry to create, construct, optimize, and dispose technology. Studies reveal that problemsolving skills such as the recognition and localization of a problem, the development and testing of a solution, and finally the evaluation and reconsideration of a problem can be promoted at primary level (Ahlgrimm et al., 2018; Beinbrech, 2003; Mammes & Zolg, 2015).

1.5. Problem Outline - Technology Education under the demands of Inclusion at primary level

Based on the ratification of the UNCRPD in Germany, the reform issue of inclusion is associated with requirements for the transformation of schools, education, and society at different levels (Trumpa & Franz, 2014). The intention of inclusive education is to further develop teaching in the direction of reducing barriers to learning for all children and considering different prerequisites (Booth & Ainscow, 2016; Grosche, 2015). Therefore, the focus here is on microstructural considerations for the further development of teaching under inclusive demands (Trumpa & Franz, 2014).

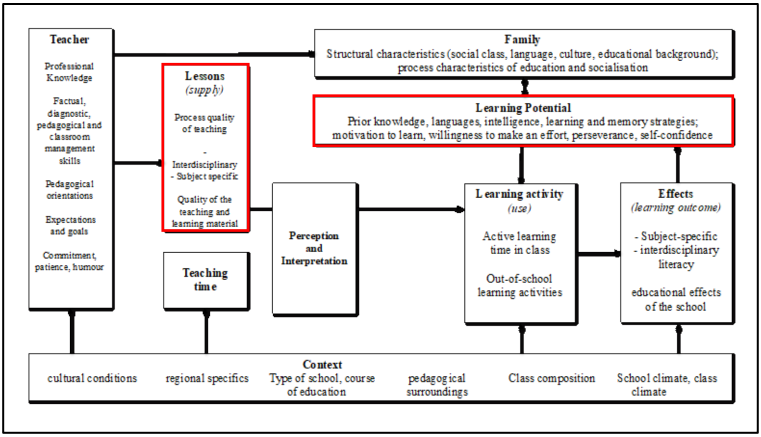
To identify a specific starting point, one must first ask the question, which sub-areas of teaching and learning must be reconsidered under the requirement of inclusion. According to Schröer and Tenberge (2022) the design of inclusive 'Sachunterricht' forms a cross-sectional task that affects the design of teaching and learning in task design and arrangement. Educational research in Germany is permeated by the use of different understandings of inclusion (Grosche 2015). Therefore the little amount of empirical studies on the design of equal and adaptive teaching and learning environments are often hard to put into comparison as they use varying degrees of focus on children affected by marginalisation and varying personal attributes inducing marginalisation. For the development and evaluation of the inclusive learning environment for technology education in this paper, we utilized a definition of Inclusive education focussing on an assumed wide heterogenity of learning individuals' potentials and needs in a classroom regardless of their predetermined personal attributes, such as gender, race, cultural background or (dis-)ability. In this respect, 'Sachunterricht' in general and technology education, in particular, with its hands-on and minds-on approach to learning, are considered to hold certain potentials for the design of inclusive teaching (Hinz, 2011). The basic principle of adaptive teaching has been identified as a reasonable approach to address the assumed heterogenous learning prerequisites of pupils (Simon, 2015). However, the outlining of the prerequisites of pupils is carried out under different theoretical presuppositions. Pupils are described in terms of their preconceptions and abilities (Möller et al., 2006), their preferred sensory channels (Gebauer & Simon, 2012) or, as in this case, their diverse kinds of needs (Schröer & Tenberge, 2021). National and international research and educational policy has so far repeatedly emphasized the relevance of needs (Ainscow, 2007; Feuser, 1989; Schumann, 2009; Simon, 2015), yet still they are rarely integrated into the development and design of inclusive 'Sachunterricht' (Schröer & Tenberge, 2022).

1.6. Suggested solution - Adaptivity as a framework for an inclusive task design

According to Helmke (2021) the interdependence of teaching and learning from a constructivist standpoint can be described in a model of supply and use. The model contains of external entities to the individuum and internal preconditions that determine each other in a complex way (Fig. 1).

Adaptive learning environments place particular emphasis on the optimal use of learning opportunities by all pupils with their individual learning potential (Hardy et al., 2011; Simon, 2015). This paper highlights especially pupils' needs that form one sub-area of their learning potential. A great variety of different ways of using and delivering lessons can be assumed, as the sub-areas of the model are interdependent (Helmke 2021, p. 71).

Figure 46. A supply-use model of the impact of teaching (Helmke 2021, p. 71 – translation by FS)



Therefore, our basic assumption is that offering pupils adaptive task formats reacting to diverse expressions of the needs for autonomy, social relatedness, and experience of competence, based on the theory of basic psychological needs (Ryan & Deci, 2018), meets fundamental requirements of the design of inclusive 'Sachunterricht'. This approach intends to address the diversity of supply and use in relation to the different needs of students (Schröer & Tenberge, 2021).

In addition, our assumptions are driven by the specific way of designing and arranging tasks for 'Sachunterricht'. According to Fischer (2014) task formats should allow not merely the transmissive replication of culture, but also, it's transformation and renewal. Our approach looks at tasks in isolation, but also integrates other basic features of 'Sachunterricht', such as learning in the zone of proximal development and scaffolding (Möller, 2012; Vygotskij, 1978). Nevertheless, the tasks are emphasized in this article as they are considered to hold potentials for the design of inclusive teaching and learning (Lütje-Klose, 2013) and were therefore used as a starting point for the adaptation of teaching.

According to the arguments, the following two research questions can be derived:

(i) How can an adaptive set of tasks be designed that can take diverse expressions of pupils' needs for autonomy, social relatedness, and competence into account?

(ii) What are the learning outcomes in terms of problem-solving skills and self-related cognitions (interest, self-efficacy, experience of competence) of lessons adapted based on the tasks designed?

According to Schomaker (2019) the design of inclusive teaching cannot be achieved by redesigning tasks and methods alone. The question of the contents for inclusive education of the subject 'Sachunterricht' must be dealt with under changed preconditions as well. So before dealing with research procedures and methods to find a humble answer to the questions above, the following chapter will describe and substantiate the technology related content for the lessons designed.

2. PROMOTING TECHNOLGICAL PROBLEMSOLVING WITH LEARNING ROBOTS

The diverse environments children grow up in are increasingly permeated by digital technological artifacts and processes (Blümer, 2019; Goecke et al., 2021). Kids although of young age play with digital toys and use digital tools daily.

In recent years everyday activities are being performed more and more by robots, i.e., "independent" mobile machines that can carry out a pre-programmed task in a defined environment. These robots can usually be described in terms of elements of input, processing, and output. They contain sensors, processors, and actuators. However, robots are in almost every case designed as so-called black boxes, meaning their way of functioning is not apparent. Through their seemingly self-determined "behaviors" but also through malfunctions or the completion of more complex tasks, they spark the interest not only of children. As the jobs robots perform become increasingly fundamental and complex through higher computing performance and machine learning functions, the importance of a basic understanding of how robots work increases.

To promote basic understandings of how robots work, e.g. the unambiguity of commands, the principle of input, processing and output, and the translation of everyday language into programming language and vice versa are of importance. By implementing this content, it is hoped to promote participation in a robotized society and computational thinking skills for all children.

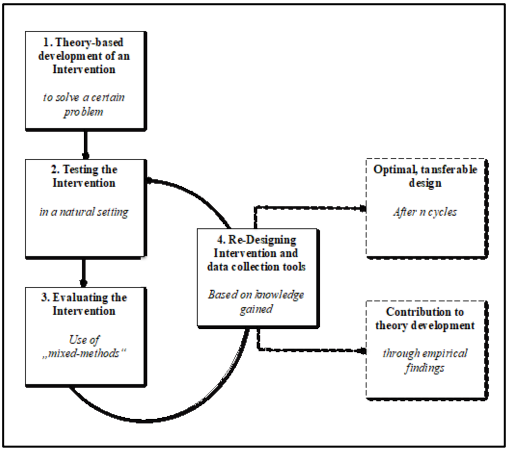
3. METHODS AND PROCEDURES

So far, existing materials for problem solving with robots or programmable learning materials are often designed in a strongly instructional way in the first access due to their complexity. Hence, they only partially meet the requirements for hands-on *and* minds-on learning activities. Considering the requirements of inclusive teaching, learning materials on the subject often require learners to have strong language skills. The existing materials that only require basal capacities are often designed as gaming and therefore from a technological perspective non-finally oriented. Hence, in our project we designed an own set of materials and tasks using the learning robot *Bluebot*™. It is especially designed for educational purposes at elementary and primary level.

Figure 2. Bluebots and task formats (by Till Verch)

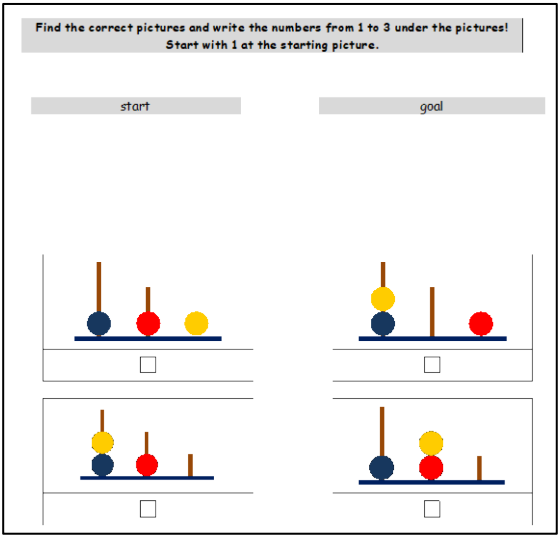
Located in the methodical framework of Design-based-research (Gess et al., 2014; Reinmann 2005), we created a set of tasks (see chapter 4.1) and materials under the theoretical requirements of inclusive education and basic psychological needs theory (Fig. 3 ad 1). It is designed so that teachers can adapt it to different expressions of pupils' needs. The tasks therefore include different degrees of freedom, can be tackled in different social forms, and are designed in such a way that pupils can adjust the level of difficulty autonomously.

Figure 3. Procedure of Design-based Research (Gess, Rueß & Deicke 2014, p.12 – translation by FS)



The presented learning setting was explored and tested with a seminar course of pre-service teachers in the winter term of 2022. After adaption of the materials to the target group of primary school pupils (n= 71) the planned lessons and materials were tested on two project days in three classrooms in a primary school (Fig. 3 ad 2). The lessons were evaluated in a first cycle by collecting quantitative data about the promotion of problem solving skills, situational interest, and self-efficacy, with yet established instruments (Bohrmann, 2017) (Fig. 3 ad 3). The pupils were tested on their development of content-independent problem-solving skills with a revised version of the Tower of London for group testing (Fig. 4).

Figure 4. Item 1 – Tower of London group Test for the assessment of problem solving skills (Bohrmann, 2017, p. 341 – translated by FS)



Data on situational interest (e.g. *"I really want to learn more about problemsolving with robots."*), self-efficacy (e.g. *"I feel confident to answer difficult questions about robots."*) and experience of competence (e.g. *"I know a lot about robots."*) were collected by written survey using a four-point Likert scale (Bohrmann, 2017, pp. 408). Further data was available e.g. in the form of pupils drawings, but were not systematically collected. Accordingly, these data sets are used here for illustrative purposes only.

The first testing of the intervention was conducted under exploratory purposes. Therefore, no control group was included in the sample. Hence, for the evaluation of the quantitative data descriptive evaluation methods are used to a large extent. The pupils were informed that participation was voluntary. All pupils had a declaration of consent for participation from their legal guardians.

4. FINDINGS – DESIGN AND EVALUATION OF AN ADAPTIVE TASK SET

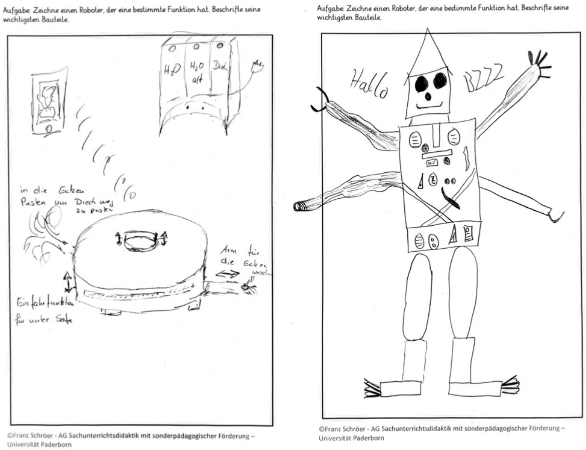
The basic idea of combining transmissive and transformative tasks was redeemed by using plugged and unplugged learning supplies. The two unplugged tasks presented in the following chapter intend to introduce the topic of robots and how they work. They stimulate contexts in which robots do not yet exist. The *plugged* examples presented afterwards tend to be more transmissive in nature. They address everyday contexts, where robots already do exist or are easy to conceive.

4.1 Unplugged supplies for learning about robots

One introductory task is to program the teacher first and a classmate afterwards. The objective is to stimulate a basic understanding of the unambiguousness of commands. Contexts addressed are e.g., putting on a jacket or pullover by voice or written commands, brushing teeth or drinking a sip of water. Some pupils used the supply to develop their own contexts for example putting on, taking off a schoolbag or opening and shutting a pencil case.

Another unplugged task is drawing a robot with a function of one's own devising. The outcomes of the task are characterized by extreme diversity. Similar to the research by Müller and Schulte (2017), the drawings show both humanoid robots with simple or complex abilities but also transmissive drawings of robots from the children's living environment, e.g. cleansing roboters (Fig. 4). The task could be extended to include, for example, the labelling of components or an oral explanation of the functions. For raising data about children's preconceptions about robots they were asked to write down useful components of a homework robot.

Figure 5. Two different robot drawings



4.2 Plugged tasks for learning about robots using the learning robot Bluebot™

The Bluebot learning robot can move forwards and backwards and perform 90 degree turns. According to the manufacturer, it can store 200 commands and execute them consecutively. Via Bluetooth connection it be programmed block based as well.

To ensure sufficient complexity of the tasks we used a map of 24 squares (6x4) the Bluebot can be moved on. To get used the basic functionality, pupils solve several simple start-finish tasks at first, where obstacles, interim targets, or restrictions (e.g. robot can only turn left) can make finding one solution, an optimal solution or several solutions more difficult. By using sticky-notes tasks can easily be adapted or modified by the pupils themselves.

When the pupils are familiar with the functions, they can move on to problem-solving tasks that borrow elements from their living environment. The tasks often require the combination of real-life and logical technical requirements.

4.2.1 A robot for postal services

In the postal-service task the pupils are asked to place several houses and a post-office on the map and deliver a defined amount of mail to the houses on the shortest way possible. The level of difficulty can be adjusted relatively easy by the placement of the objects. As the pupils progress in the task, the optimal placement of the post office becomes a virulent problem as for example parcel delivery stations are often located in peripheral, but a logical placement would rather be in the middle of the map. In this way, different areas of demand on technological processes can be illustrated and discussed. During the task, it is often discussed what other functions the *Bluebot* would need to be a good postman. Here, there are learning opportunities to talk about actuators and sensors, for example.

4.2.2 A school bus robot

A more structured context used is to program the Bluebot as a school bus robot where the starting point of the bus, the school building and several traffic lights are pre-defined. Again, pupils often argue about different requirements for the optimal route to take. A common issue here is whether the school bus is only using main roads or side roads as well.

4.2.3. A robot for vacuuming and mopping

Where is the optimal place to start when navigating all over the map? A fundamental question for this task is where the best place for the charging station is and how all fields of the map (i.e. the whole room) can be cleaned. Mopping is restricted by the additional condition that the water tank must always be refilled at the charging station after ten mopped fields. This leads to the question how passing fields already cleaned can be avoided and whether there is a solution, where no field must be crossed twice. Again, logical, and real-life requirements come into play as in real-life charging stations are not placed in the middle of a room. As the chains of command become very long, this task is a good opportunity to talk about further requirements for a cleaning robot and how linear command chains are not sufficient for every type of requirement.

4.2.3 Two robots dancing

Programming two robots in a synchronous or exactly asynchronous way requires precise agreements among the students and good communication in the team. A sequence of dance steps can be varied greatly in complexity and the pupils can decide autonomously, how a dance pattern should be arranged.

4.2.4 A robot doing whatever

In a final task-format the pupils are asked to design their own task for the others in their class. Therefore, they first design the task one possible solution and learning supplements such as symbols for the map. As the creators of a task act as experts, peer-to-peer learning is promoted and the need for social relatedness can be considered in a comprehensive way.

4.2.5 On the reflexive engagement

In addition to reflection on the functional principles and components of robots, the tasks presented also provide the opportunity to stimulate discussion of strategies in the sense of problem-solving and computational thinking. Furthermore, participative, and social structures in class can be looked at retrospectively and, if necessary, transferred to other settings. There are further potentials in the use of more symbol-based programming environments, such as the micro-controller Calliope-mini™ or in the use of sensor-controlled robots, such as the Ozobot™.

4.3 Empirical Findings from the first lesson cycle

The sum value for problem solving skills of the participating pupils changed from a mean value slightly below the arithmetic mean in the pretest (*M = 2.127; SD = 1.74; α = .762*) to slightly above (*2.5*) in the posttest (*M = 2.953; SD = 1.98; α = .870*). On average, the participants scored *M = 0.796* (*SD = 1.405*) points higher in the posttest than in the pretest, whereby 5 points were the maximum possible in the test.

Since a uniform perception of the topic of robots in the subject '*Sachunterricht'* cannot be assumed for the pretest, the participants situational interest, self-efficacy and experience of competence were raised for the subject '*Sachunterricht*' in general in the pretest and the topic of robots was integrated in the posttest. An overview of the descriptive results on self-related cognitions is presented in Table 1. One item had to be removed from the scale for situational interest due to lack of correlation with the construct ('In the lessons I had to make an effort to listen.')

Table 23. Descriptive findings for self-related cognitions

Variable (number of Items)	**Pre-Test** Likert scale 1-4	**Post-Test** Likert scale 1-4
Situational interest (5)	M = 3.067 SD = .527 α = .636	M = 3.569 SD = .390 α = .683
Self-efficacy (5)	M = 2.963 SD = .726 α = .771	M = 2.991 SD = .646 α = .737
Experience of competence (7)	M = 3,179 SD = .732 α = .812	M = 3.396 SD = .448 α = .822

Also, based on repeated testing in other studies (Bohrmann, 2017), a satisfactory fulfilment of the statistical test quality criteria can be assumed. The data on situational interest are interpreted accordingly with caution.

4.3.1 Promotion of Problemsolving Skills

Since the research design did not include a control group, the comparison of the test scores in the pretest and posttest is based on the comparative mean value from Bohrmann's (2017) pretest (1.6502). Accordingly, a one-sample t-test was calculated. Table 2 shows that the mean value does not significantly differ from the comparative value in the pretest. The post-test mean value does differ from the comparative value on a highly significant level.

Table 2. Significant difference in problem-solving skills Pre to Post

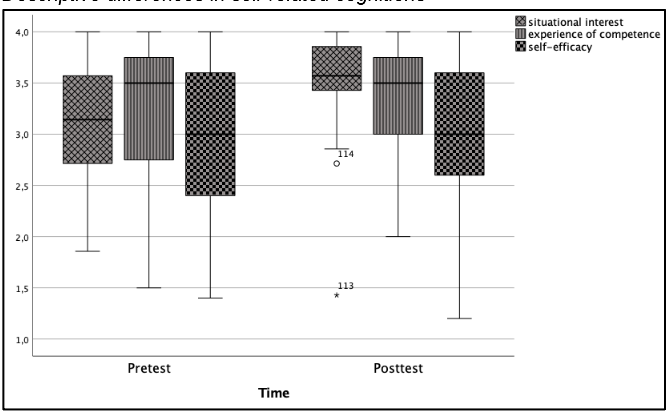
Variable (comparative value = 1.6502)	**T**	**df**	**bilateral p**
Problemsolving (pretest)	2,308	70	.024
Problemsolving (posttest)	5.266	63	<.001

Accordingly, the lessons are associated with a cautiously interpreted mean effect on problem-solving ability (*Coh.-d = .658*). Furthermore, a strong, highly significant correlation among pretest and posttest must be taken into account (*Coh.-d = .721**; p = <.001*).

4.3.2 Development of self-related cognitions

For the surveyed self-related cognitions, no comparative values could be adopted in advance. Accordingly, an effect of the lessons can only be hypothesized here. It can be assumed, that especially those pupils with a low experience of competence felt more competent regarding the topic of robots in the post-test as the the bottom quartile decreases. This applies in a similar way to situational interest in the pretest to the posttest. However, the interval in which promotion takes place seems to be longer. For the pupils' self-efficacy, no significant promotion can be assumed (Fig. 5).

Figure 6.
Descriptive differences in self-related cognitions



5. DISCUSSION AND OUTLOOK

Based on the interpretation of the results, our research questions about the design of materials and the promotion of problem-solving skills and self-related cognitions can be answered as follows.

In essence, it can be assumed that the lessons are conducive to the problem-solving ability of the pupils, although the use of a control group and possibly a baseline is necessary for the coming cycles to be able to calculate test learning effects and other external effects.

A promotion of self-related cognitions can be assumed for the interest in the topic and the perceived own competence but not for self-efficacy.

It is open to what extent pupils with certain expressions of psychological needs benefited from the lessons. The expression of needs seems to be an additional variable in this respect. Alternatively, self-directed teaching settings could be compared in intervention studies, following the preliminary works of Tenberge (2002) and Beinbrech (2003) in another cycle. Targeted variations regarding the needs for experiencing competence and social relatedness also seem to make sense.

We see great potential in terms of researching pupils' preconceptions in the use of labelled or orally explained drawings of robots (Möller & Wyssen, 2018).

Finally, the observations that have not yet been systematized have led to the assumption that a targeted adaptation of language-sensitive learning supports (e.g. through pictograms) could be of interest. Particularly in the case of pupils with an already high level of ability, the development of challenging problems and the integration of further programmable teaching materials is still pending.

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Promoting Creativity in the Secondary Design and Technology Classroom in England

Venessa Lourdes Silveira, University of Georgia, venessa.silveira@uga.edu
Paul K. Mburu, Harlington School, pmburuus@yahoo.com

ABSTRACT

This study explores the use and implications of biomimicry as a design method in a secondary school Design and Technology classroom in England. The study's aim was to explore biomimicry as one of the design approaches in a Design and Technology classroom. The goal of this research was to develop an appropriate teaching strategy for including biomimicry in the design process as a means for encouraging students to "use a variety of approaches to generate creative ideas and avoid stereotypical responses when responding to design briefs" (DfE, 2013, p. 2). The Biomimicry approach takes inspiration from natural solutions adopted by nature and imitates the concepts when designing products. Working with a class of year 9 pupils (aged 13 - 14) the research team introduced the principles of biomimicry, which was chosen as an innovative approach for promoting creativity. This action research took a qualitative approach to gain insights into pupils' thought process as they applied biomimicry in the given design brief. Action Research was used to understand if the introduction of biomimicry as an intervention would develop pupils' creativity. The data that was used for analysis includes responses to open-ended questions, drawings, and artefacts. The findings of the study show that with the support of teachers, pupils used inspirations from nature in their design and make tasks to creatively think through and create original artefacts that meet an identified design need. The biomimicry approach was embraced by pupils who developed a range of nature inspired designs. The paper also presents interesting findings on pupils' knowledge and learning process through demonstration of acquired skills of originality and creativity represented through interventions in nature.

Keywords: Biomimicry, Design and Technology, National Curriculum, Creativity

1. INTRODUCTION

As part of the National Curriculum in England, Design and Technology education is a subject taught at both primary and secondary school level until key stage 3 (ages 11-14), thereafter pupils at key stages 4 and 5 (ages 15-18) may choose to study the subject further. As a subject department, Design and technology is made up of several subject specialisms. Consequently, the teaching of Design and Technology assumes different forms depending on the school and the unique context of a specific department (Mburu, 2022). The National Curriculum underscores in its purpose of study for Design and Technology that 'using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts' (Department for Education (DFE, 2013, p.1). With a focus of importance drawn towards this, Nicholl, Flutter, Hosking, & Clarkson (2013) allude that design problems should be based on authentic, real-world problems which can be both meaningful to pupils' and deploy the use of tools in the design community. Katherine K. Fu et al. (2019) outlines design fixation as a blind adherence to a set of ideas or concepts limiting the output of conceptual design which can have negative effects on the design process. Furthermore, they argue that design fixation is relevant to design practitioners and educators through several investigations that observed significant manifestations in both pupils' and experts when provided with an example solution (p.3). Considering the potential negative impact design fixation can have on the design process and outcome, it is crucial to find effective ways to prevent design fixation. Encouraging pupils in Design and Technology classrooms to develop creative solutions to real-life problems by using design inspirations from nature and moving away from design fixation is central to this research.

8.1. Using Biomimicry as a Design Approach in an English Secondary School.

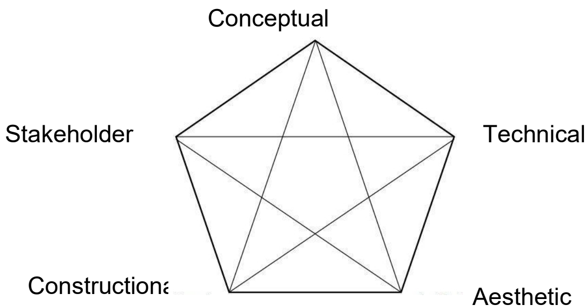
The term 'Biomimicry' first appeared in scientific literature in 1962 and gained popularity among material scientists in the 1980s (Pawlyn, 2019). Biomimicry is an approach used in different branches of science that studies nature's models and processes to solve human problems through design inspirations and imitation. The design process is approached in a way that designers look at nature, ecosystems, or a specific organism by imitating these behavioural processes to solve human problems. Although this approach is not new, it was immensely promoted by biological sciences writer Benyus (1997) who describes biomimicry as a process inspired by nature to drive innovation and improve current methods of product design, manufacturing, and life cycles. In other words, Vierra (2019) and Appio et al. (2017) describe biomimicry as the science and art of emulating nature's best biological and sustainable solutions by emulating patterns and strategies that have been tested through time in nature. Consequently, this approach of imitating design ideas from nature can be useful in helping pupils grasp design concepts and provide an authentic learning experience in design and technology classrooms. This application of using biomimicry as an approach in a Design and Technology classroom in England aligns with the learning objective in the National Curriculum framework DfE (2013) in England which states:

> When designing and making pupils should be taught to use a variety of approaches. For example, biomimicry and user-centred design, to generate creative ideas and avoid stereotypical responses (p. 2).

Biomimicry affords a pedagogical approach which places a pupil as a creative thinker and designer to work jointly with others on an actual real-life design problem. This way of working gives a Design and Technology learner the opportunity to avoid generating product design ideas that are a direct copy of what they are familiar with. Furthermore, the two main categories of using biomimicry as a design approach are; where a designer directly mimics strategies of an organism, a behavioural pattern, or a system in nature and where the designer abstracts ideas and concepts as principles from nature's designs (Elmeligy, 2016). Drawing from Barlex and Steeg's (2017) interdependent decision-making approaches, this study seeks to understand the significance of biomimicry as a design method in a Design and Technology classroom.

According to Barlex and Steeg (2017), designing and making is often seen as the heartland of design and technology education. Mostly, designing and making often go hand in hand in a design and technology classroom. However, each of these could be taught separately to pupils. Barlex (2011) argued that designing is the act of generating, developing, and communicating ideas for products, services, systems, and environments in response to what the user needs and wants. This notion of designing is also associated with ideas that show creativity and originality. Creativity and designing are interconnected. According to Cox (2005) creativity is the generation of new ideas while innovation is the successful exploitation of new ideas and design is the linkage between creativity and innovation. Benson (2017) states design and technology as a subject in schools provide immense opportunities to pupils in many ways to develop their own creative skills (p. 8). Klapwijk and van den Burg (2020) highlight the importance of creating such a space for pupils to stimulate them to develop creativity in learning. However, ensuring pupils generate ideas that show creativity could be challenging for teachers when considering how to meet the national curriculum objectives in design and technology education. Barlex and Steeg (2017) developed a diagram (figure 1) that visualises the concept of decision making that pupils need to undertake when they are designing and making.

Figure 1.
Five key areas of interdependent decision making (Barlex and Steeg, 2017)



The interdependence of these five areas is an important component of making design decisions, as change of decision within one area will affect some if not all of design decisions that are made within the others (p.16). It is the juggling of these various decisions that leads to a clear design proposal that can then be achieved to the point of a fully working prototype. This process of designing and making that requires intellectual rigour is an essential part of design and technology education.

In secondary school Design and Technology classrooms, design challenges are often based on real-life design briefs or imaginary ones. Pupils gather and collate a range of information to help them generate solutions to an identified problem. The solutions are presented using a range of methods including two-dimensional (2D) and three-dimensional (3D) drawings and 3D models. In the final stage in the design cycle pupils make and evaluate their products, which could be working models or prototypes. In this action research the concept of biomimicry is explored in the setting of a classroom intervention to enhance creativity. The concept of decision-making process in the classroom followed the Barlex and Steeg (2017) model. The biomimicry-based project was aimed at encouraging pupils to acquire both knowledge and skills including designing and making. The aim was to help pupils acquire a set of skills to generate design ideas that showed originality and creativity. The main research question is: How do pupils move away from design fixation when exposed to interventions based on nature?

9. METHOD

This study adopted an action research approach, a process that helps practitioners develop a better understanding about the particulars of a specific practice-based situation (Wilson, 2013). It is assumed that in a classroom situation, research action provides teachers with an opportunity to engage in actions that would improve the learning opportunities for their pupils. In this case, the practitioners include a qualified teacher of Design and Technology and a teaching assistant with an advanced degree in design education. The action research applied qualitative methodology to interpret responses to open-ended questions, drawings, and artefacts. The research involved a series of ten lessons adopted from Nicholl et al. (2013) which was divided into pre-intervention, intervention, and post-intervention phases. The pre-intervention phase required preparing a set of teaching resources to introduce pupils to the concept of biomimicry. Pupils were given a design brief that was sent by a real client, which was a primary school neighbouring the school. The design brief emphasised a real-life problem for the client. The client stated that they required 'a range of nature inspired products that would encourage wildlife habitation in their school compound'. The design limitations were to create a range of products that would be safe for the children in the school compound and welcome wildlife such as birds, squirrels, hedgehogs into an identified space in the school.

In the first week, the classroom task involved sharing the design brief with the pupils in a normative classroom setting. This was followed by watching a video on wildlife in their habitat in England. After a short classroom discussion, a questionnaire with open-ended questions was given to pupils. The questionnaire was to be completed during a short visit to a forested area outside of the school. This visit took forty-five-minutes and pupils made observations from nature and recorded them on the questionnaire worksheet. Pupils were also encouraged to write questions that they thought needed to be answered. Pupils recorded their observations as written notes, drawings of nature-based items such as nests of animals, leaves, trees, insects, and fruits. In addition, pupils were given a home learning task that involved compiling a piece of research on the homes, colours, textures, sizes, and behaviour of different wildlife. This was intended to give pupils an opportunity to consider how two or more elements would influence their designs. Furthermore, this was aimed at encouraging the use of reasoning and thinking skills throughout the process whilst developing their design ideas.

In the second week of the project, pupils were shown images of the client's compound. These images, the information that was collected during a classroom visit to a forested area, knowledge gained from the previous week's lesson, and the additional findings from their home learning task were used as materials to inform the designing tasks. Pupils spent forty-five minutes generating ideas for a product that would home their chosen wildlife in the client's compound. Ideas were recorded using sketches and cardboard models. The lesson (one hour forty minutes) in the third week involved pupils' modelling their ideas using cardboard. This was the intervention phase where pupils were shown images of products that had been designed using the concept of biomimicry. Pupils were encouraged to use their field visit observations, drawings of natural items (as observed and recorded during the field visit session), and the classroom intervention materials to integrate biomimicry concepts in developing their design ideas. Pupils spent another lesson (one hour forty minutes) developing and testing their ideas using cardboard models. The aim of these modelling sessions was to test and try their models whilst using various inspiration from nature. Pupils then developed a final cardboard model in readiness for prototyping. The post-intervention phase involved pupils making their refined final design using pine. This phase took three weeks, that is, five lessons of one hour forty mines. Table 1 presents the structure of the lessons compared to Barlex and Steeg (2017) approaches to decision making.

Table 24.
The structure of lessons compared against Barlex and Steeg (2017)

Lesson	Length (Minutes)	Instructional strategies used in this study	Barlex and Steeg (2017) approach
1 – Pre-intervention	45	Introducing the client Discussing the design brief	Stakeholder Conceptual
	45	Visit to a natural habitat that neighbours the school	Conceptual
2 – Pre-intervention	First 45	Pupils were shown images of the client's compound	Stakeholder Conceptual
	45	Generating ideas Modelling ideas	Aesthetic Technical Constructional
3, 4 and 5 Intervention	140 each	Generating ideas Modelling ideas using cardboard Intervention introduced	Aesthetic Technical Constructional
6, 7 and 8 Post-intervention	140 each	Making the final product	Aesthetic Technical Constructional Stakeholder

10. DATA ANALYSIS

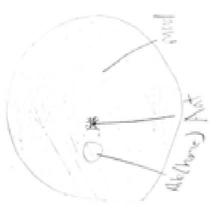
The biomimicry approach in this study was aimed at encouraging pupils to acquire both knowledge and skills in designing and making. This section represents the three stages of the 'think, design and make' process that defined the project methodology. Pupils' curiosity about the environment and different functions of nature were projected through the types of questions they asked. It was observed that pupils were able to express thoughts, ideas, and curiosity about the natural world after intervention through the questionnaire tool that was used by teachers. The questionnaire tool presented questions such as name two or more wildlife that you observed, describe the details of any animal home structures, sizes, behaviours you may have observed, questions you would like to be addressed and note anything you are curious to know more about. This section presents data from four pupils: Alfie, Maria, Thomas, Zafar (pupils names are pseudonyms). The data presented shows pupils' questions, drawings, models, and final products to provide a view of their shift in thinking through their individual design journeys.

Table 25.
Transition in Alfie's questions before and after intervention

Initial design thinking process before intervention	**Curiosity projected through nature of questioning after intervention**
The nest must be in a place where it's not too crowded and a place where it won't get damaged.	How long does it take for the bees to find their queen and a home?

Considering the above questions in Table 2, Alfie's inquisition moves from general knowledge on the behaviour of the wildlife they were investigating to a more specific question to support his designedly thinking. This process of thinking and the use of nature based intervention materials helps him to ideate a living space for a chosen wildlife, make quick models and develop a prototype, which are shown on Table 3.

Table 3.
Three stages of Alfie's drawing, modelling and making

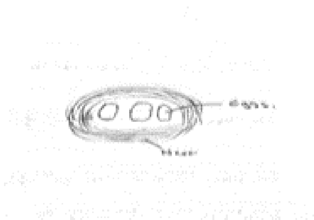
Initial drawing	**Final development of the cardboard model**	**Final prototype**
		

The questions asked by Maria in table 4 moves away from the most obvious need of a home for wildlife to identifying other possibilities that are essential. Maria applied her knowledge of spaces which was triggered by the intervention tasks to consider other factors in her 'think, design and make' process as shown on Table 5. Her shift in thinking through the transition in questions implies that she was thinking about animal sizes and safety through her observations in nature.

Table 4.
Transition in Maria's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
I want to make more homes for wildlife on the ground so it can attract other animals besides birds	How are we going to find the right space to place the homes we make for the animal?

Table 5
The three stages of Maria's drawing, modelling and making

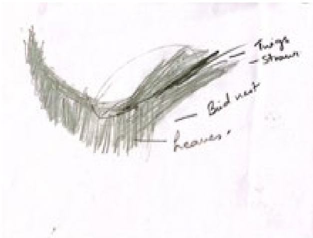
Initial drawing	Final development of the cardboard model	Final prototype
		

In addition, Zafar's question before intervention is an example which implies a shift in thinking from a generic question to a more specific solution-based response. Zafar's thinking is illustrated on table 6 also shows the use of leaves as 'safe homes' to protect wildlife such as birds.

Table 6.
Transition in Zafar's questions before and after intervention

Initial design thinking process before intervention	Curiosity projected through nature of questioning after intervention
How do we make the right home for wildlife?	We could plant more trees around the school to protect the animals and their habitat

Table 7 Three stages of Zafar's drawing, modelling and making

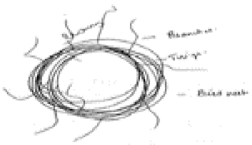
<table>
<tr><th>Initial drawing</th><th>Final development of the cardboard model</th><th>Final prototype</th></tr>
<tr><td>
</td><td></td><td></td></tr>
</table>

Thomas's understanding of the basic behaviour of his chosen wildlife led him to develop a product that is functional as illustrated on Table 8. The guiding principle for Thomas was that the product had to look 'safe' and allow the wildlife to 'come out at night'.

Table 8.
Transition in Thomas's questions before and after intervention

Initial design thinking process before intervention	**Curiosity projected through nature of questioning after intervention**
There must be more holes and enclosed spaces, so the animals feel safe	Why do hedgehogs come out only at night?

Table 9
Three stages of Thomas's drawing, modelling and making process.

Initial drawing	**Final development of the cardboard model**	**Final prototype**
		

The questioning tool allowed pupils to ask questions based on what they observed. For instance, pupils asked questions that showed curiosity about the environment around them. For example, Thomas asks, "why do hedgehogs come out only at night?" or Alfie's curiosity to know "how long does it take for bees to find the queen and a home". Engaging in such a thinking process and producing a range of questions indicates pupils' willingness to examine the contextual challenge (meeting clients' design needs) to inform their decision-making process. These questions, plus the nature-based intervention materials that were provided have the most influence in thinking outside of the obvious solutions when designing a home for wildlife. Classroom teachers would have the most impact in directing pupils away from design fixation and aligning themselves with existing solutions. In this project these problems were countered by taking pupils outside of the classroom to an actual real life outdoor space that they explored.

The importance of this approach was that it motivated and brought a new perspective to pupils'' thinking. Their developed questions as shown in tables 2, 3, 4 and 5 identified elements of wanting to solve real problems that resonated with their local situation. Examples of pupils' questions in the tables also highlight expressions of developing ecological awareness. For example, in Table 5, Thomas commented that "there must be more holes and enclosed spaces for animals to feel safe", which suggests that the pupil is beginning to understand the challenges animals could be facing in a wild space, while also trying to find design solutions to these challenges. The contextualization of the challenge made the task become more personal to them. "How are we going to find the right space to place the homes we make for the animal?'' suggests Maria's thinking beyond what she had observed. It could be inferred that the pupil is trying to inquire about possibilities for design ideas in designing and building a bird nest.

11. DRAWING, MODELLING AND FINAL PRODUCT PHASE.

The design thinking was inspired by images that pupils collected as a source of inspiration in conjunction with a visit outdoors as intervention materials. Pupils' design models display significant patterns, and mimics features found in nature. Tables 3, 5, 7 and 9 show pupils' initial drawing, final development of the cardboard model and the final prototype. In developing the models, pupils showed the process of introducing alternative solutions following evaluation of existing solutions. As seen in table 3, Alfie decided to construct a product that would attract bees. Specifically, using an insect's body structure as a starting point for the construction of the main structure of his design. The concept of housing items within the body of the insect (like a hive with holes) stimulated the idea of the holes on the product for the bees to live in. Maria took the idea of how an apple fruit keeps its seeds intact and safe inside (see table 5). She used the concept to construct a home for wildlife and in considering the aesthetic element they maintained the natural shape of an apple.

Not only did Zafar base his design in the form of a leaf but also considered the function of a leaf in a plant, as a surface for processing food. He argued that a good leaf must look tough and protect the contents inside of it. Thomas based his design on the rustic look of a tree bark and argued that the protective function of the bark makes it suitable as an outer layer for trees. Therefore, his idea was creating a home for hedgehogs that looked strong and blended in with the surrounding environment to keep them safe. In the pictures displayed in tables 3, 5, 7 and 9, individual pupils chose and designed the most favourable solution that was further improved by imitating solutions found in nature. The models are further developed by constructing prototypes, which show the use of chosen patterns that exist in nature. The final prototypes were placed in their intended environment as shown in Figure 2. The imitation of nature in the models and prototypes is evidence of analytical thinking to creatively apply new learning in design and make tasks.

Figure 2.
Images of the completed artefacts in their intended environment

12. DISCUSSION AND CONCLUSION

The goal of this research was to develop an appropriate teaching strategy for including biomimicry in the design process as a means for encouraging pupils to "use a variety of approaches to generate creative ideas and avoid stereotypical responses" (DfE, 2013, p. 2). The year 9 pupils who participated in the study recognised that they needed a range of resources to develop solutions while using nature for design inspiration. The goal of the visit to the natural habitat next to the school compound was to have pupils' experience a real-life context of wildlife habitation in a natural environment and identify patterns found in nature. This allowed pupils to integrate their observations on how wildlife live with their proposals in responding to the design brief. Discussions with pupils elicited their fixation with patterns found in nature whilst developing their optimal solutions. Pupils' recognition of nature's solutions to problems was evident in the generation and development of ideas. In using biomimicry as an approach, several factors influenced the success of the project.

In this study the design brief was to solve a real-life problem for a client who required 'a range of nature inspired products that would encourage wildlife habitation in their school compound'. In developing solutions, the pupils had to make decisions about the appearance and construction, while considering different stakeholder preferences. Such decisions include how the item works and the technical decisions, which can be a tricky territory. In the case of an item to attract wildlife, for example birds, it works by being relatively inconspicuous – an aesthetic decision. Having the correct size hole to attract certain birds was an important part of observation that was then incorporated in the achieved construction design. If the pupils were trying to attract butterflies, then the decisions would require different observations and would involve different specifications in constructing a suitable home for wildlife. The interventions provided to pupils in their design and task enhanced their responses to the identified design need. The biomimicry approach was embraced by pupils who developed a range of original and creative nature inspired products, and our findings confirm that pupils valued opportunities that involve questioning solutions presented by nature. Each of the twelve pupils produced a prototype that had an inspiration from nature, not only in their form but also the decisions behind how the products would function.

One of the findings in this action research was that the context of the department and the resources that were available to us influenced the outcome of pupils' use of biomimicry as a design approach. Further research could be designed to understand pupils' understanding of biomimicry as a design approach. This would be helpful if integrated with an understanding of how this approach improves pupils' learning outcome in their Design and Technology classroom.

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Masculinities and Femininities in the Design and Technology Classroom

Olexandra Solomka, University of Cambridge, os380@cam.ac.uk

ABSTRACT

Design and Technology is a secondary school subject that is perceived by students to be masculine and has been documented by the literature as an environment that can be considered off-putting to non-laddish masculinities and femininities. This paper posits that dominant forms of masculinity and femininity, and the characteristics that make up these forms, are highly dependent on the context in which they are being observed. Furthermore, the paper presents the findings of a small, qualitative group interview with four girls at a private secondary school in a deprived area of East Anglia. The participants were asked about their perceptions of whether specific tasks, artefacts (e.g., clock), and projects were masculine, feminine, or neutral to document which parts of the subject are most associated with masculinity. The study found that the participants' perceived confidence in the workshop to be a masculine trait, as well as any tasks or projects related to electronics or robotics. Conversely, working with textiles and creating similar projects were considered feminine. Tasks and projects that focused on problem solving, and using materials other than electronics, robotics and textiles were neutral. The paper also found that general practical tasks and building projects were considered neutral, though the participants perceived that their (masculine) teachers did not believe they were competent.

Keywords: Masculinity, Femininity, Design and Technology, Tasks, Projects

1. INTRODUCTION

This paper seeks to explore how specific tasks, practical outcomes and projects taught in secondary Design and Technology (D&T) lessons were perceived by the participants to be masculine, feminine, or neutral. The paper adopts Connell's (1989; 2020) definitions of masculinity and femininity: that the collective social practices that make up cultural understandings of gender structures (Connell, 1989; 2020) masculinity and femininity are not fixed, and come into place as people act (Connell, 2020). As such, multiple versions of masculinity and femininity can be seen throughout different microcosms of society (Connell, 2020), and thus, it is essential to explore how masculinities and femininities are manifested in the D&T classroom specifically. Indeed, the practice of categorising different forms of masculine or feminine identities in schools is seen often within the field. To name a few, we have 'pussys', 'fags', 'wimps' (Schippers, 2007), 'cool guys', 'swots', 'wimps', 'Cyrils' (Connell, 1989), 'super-girls', 'mean girls', 'ladettes' (Ringrose & Walkerdine, 2007), 'geeky girls', 'tomboys', 'mosher girls', 'lesbians', 'girlies' (Renold & Allen, 2006), 'tomboys', 'girly-girls' (Paechter, 2010), 'lads' (Francis, 1999; Dixon, 1996), 'spice girls', 'tomboys', 'nice girls', 'girlies' (Raey, 2001). Further, each category had characteristics, appearances, and assumptions that the participants understood on a local scale. Thus, this paper aims to explore the dominant forms of masculinity and femininity within the participants' school and the behaviours and perceptions of masculinity and femininity in their D&T classrooms.

1 LITERATURE REVIEW

1.1 Masculinity and Femininity in Schools

Establishing the versions of masculinity and femininity that afford social capital within the context of that specific school is vital to forming a holistic picture of the participants' belief structures. For example, within state-school settings, being middle-class, well-behaved, and academic was regularly found to count against children's social capital. Raey's (2001) 'nice girls' were categorised by other children in the class as being boring, unpopular, and well-behaved, with Raey (2001) observing that these individuals were all white, academically intelligent, and middle-class, which were contrasted with the dominant working-class majority. Likewise, Connell (1989) noted a similar status for 'Cyrils', who were academic, middle-class boys in a working-class school, where the dominant qualities of masculinity are often sporting prowess and toughness. The subordination of academic intelligence within certain schools can be understood as a rejection of middle-class femininity, with boys who display this version of femininity being effeminised by their peers and posing a threat to social order (Connell, 1989; Raey, 2001; Schippers, 2007). One way power can be claimed back by low-attaining boys is through adopting 'laddish' behaviour (Connell, 1989; Francis, 1999; Schippers, 2007), defined as "white, working-class and anti-school" (Francis, 1999, p.357). Thus, boys and girls enacting non-laddish versions of masculinity or femininity, such as academic intelligence, are perceived as contaminating and threatening to social order. The social hierarchy must be balanced through establishing academic ability with low social capital.

Of course, the construction of masculinity requires internal regulation and self-control of social and sexual instincts. To explain this, Dixon (1996) applied Berger's (1972) concept of the male gaze; an idea usually applied to how women learn to see and scrutinise themselves through the imagined gaze of the heterosexual man. Instead, Dixon (1996) called for the 'male gaze' to be applied to how boys learn to see, scrutinise, and self-regulate their behaviour and appearance to align with the dominant norms of heterosexual masculinity. Similarly, Paechter (2006) suggested that individuals learn to see themselves through the eyes of another when operating within a particular social group and are regulated by the group and by themselves. Further, the group norms are created in opposition and dichotomy with other groups (Connell, 1989; Raey, 2001; Schippers, 2007; Paechter, 2006). For example, just as masculinity is in dichotomy with femininity, the girly girl is dichotomous with the tomboy (Paechter & Clark, 2007). Thus, which version of masculinity or femininity is deemed desirable or cool depends on the environment and school in which research is conducted, as masculine or feminine identities are often constructed just as much from what they are *not* representing, as what they are.

1.2 Masculinity, Femininity and D&T

Within secondary schools, some subjects are found to be associated more with masculinity than femininity. For example, Physical Education (PE) (Paechter, 2003; Clark & Paechter, 2007; Paechter, 2010), Science, Technology, Engineering and Maths (STEM) subjects (Francis et al., 2017), and D&T (Peachter & Head, 1996; Dixon, 1996; 1998). Likewise, specific forms or versions of masculinity are associated with these different subjects within the spectrum of masculinity. For instance, D&T and PE appeal to many of the qualities associated with laddish-ness. This could be due to the physical nature of working with one's hands, which was considered a working-class masculine endeavour, and the taking home of D&T artefacts as a symbol of working-class manhood (Paechter & Head, 1996). This perceived working-class status of D&T and PE, and subsequent appeal to laddish boys, meant that teachers of D&T and PE formed close relationships and associations with "disaffected and working-class boys due to their more informal teaching arenas" (p.24). Here, boys could display laddish behaviour, often without punishment, creating an environment where 'mucking around' became the main aim of the lesson (Dixon, 1996, p. 150). As a result, to control this 'rowdy' behaviour, teachers of D&T need to display domineering 'chief wolf' type teaching styles to maintain control of rowdy or laddish behaviours (Anglim, 2021). Indeed, this teaching and behaviour management style can be off-putting to non-laddish, high-attaining, and feminine types of students (Anglim, 2021; Dixon, 1998). Thus, this could be one of the reasons why D&T is perceived as the domain of working-class masculinities (Dixon, 1996; 1997; 1998). Thus, the masculine identity of the subject has been repeatedly perpetuated and reinforced by both students and teachers.

Due to these masculine associations, certain girly-girl, super-girl, or nice-girl versions of femininity may be formed through resistance to masculine subjects like D&T or PE (Paechter, 2003). Also, many of the qualities required to be good at subjects like PE and D&T are associated with masculinity, e.g., physical strength, competitiveness, aggression, and large stature; thus, if wishing to exert femininity, there is a reluctance to be seen as to be good at them (Clark & Paechter, 2007; Dixon, 1996; 1998). Correspondingly, the literature suggests that girls tend to be more nervous around tools and practical tasks, with teachers perceiving that they need much more encouragement and reassurance when tinkering or building (Dixon, 1996; Peachter, 2006; Anglim, 2021). However, Anglim (2021) found that when teaching single-sex classes, teachers reported that girls were more confident, even when tackling masculine materials such as electronics and programming, potentially due to the removal of stereotype threat (Anglim, 2021).

Such initiatives have been implemented via interventions designed to facilitate femininities in the D&T, and encourage girls to tinker and build confidence in the workshop.

Furthermore, creating spaces for girls to operate safely and openly within the masculine domain of the D&T workshop allowed girls to feel protected and playful and removed the fears they had about being the only girl in D&T (Betser et al., 2022; 2019; Betser & Martin, 2018), and encouraged them to take on more valued, non-stereotypical project roles in group work (Betser et al., 2019; Buchholz, 2014). However, facilitating single-gender D&T environments in the timetabled school day is potentially logistically complex and would require more than just the classroom teacher's input. Likewise, it takes more of an essentialist perspective on masculinity and femininity. It considers children as simply boys and girls, while we already know that there are laddish boys, academic boys, tomboys, and girly girls.

2 METHODOLOGY

This study forms a preliminary phase of a larger body of research performed as part of the author's ongoing PhD in Education at the University of Cambridge. The study was undertaken at a private, mixed-gender secondary school in a deprived area East Anglia, and the participants were four Year 9 girls. Data collection took one afternoon. During the study, the participants were asked to answer a series of questions and undertook several activities during semi-structured, photo-elicitation group interviews. The interview was audio recorded and then transcribed. During the interview, the participants were asked to consider the activities they might do during a D&T lesson. Once the participants had established the list, they considered and discussed whether those tasks were masculine, feminine, or neutral. Following that, the interviewer gave the participants a set of 22 photographs of D&T artefact outcomes, e.g., images of completed projects such as cotton tote bags or steel paperweights. The participants were asked to rank them in order of most masculine to most feminine. Next, the participants were presented with eight sample D&T projects, and the interviewer provided an explanation and visual guide as to what would be involved in each project; e.g., participants were presented with visual examples of the planning, designing, and making stages of each project. The participants were asked to order the projects from most masculine to most feminine.

3 FINDINGS

Table 1. *Participants' perceptions of masculine, feminine and neutral artefact outcomes in D&T*

Order from most masculine to most feminine	Artefact Outcome
1 (most masculine)	Raspberry Pi arcade machine
2	Kitronik robotics project

3	Lego Wedo robotics project
4	Kitronik soldered electronic memory game
5	Speaker/radio project
6	Metal paperweight project
7	Pine trebuchet project
8	Electronic steady-hand game
9	MDF phone stand
10	Pine bird box
11 (neutral)	Wooden box
12	Architecture project
13	E-textiles pencil case
14	Clock (free design)
15	Designing Our Tomorrow Asthma Challenge
16	Sensor project
17	Clock (Memphis style)
18	Pewter keyring
19	Cotton tote bag
20	Micro:bit moisture sensor plant watering
21	Embroidered cushion
22 (most feminine)	Upcycling

Table 2. *Participants' perceptions of masculine, feminine and neutral project processes.*

Order from most masculine to most feminine	**Project title**	**Project process**
1 (most masculine)	Kitronik Soldered Electronic Memory Game	Creating a digital mood board of memory games Learning about resistor values and how to read them. Soldering.
2	Wooden Pine Trinket Box	Creating an isometric drawing of a trinket box. Practical lessons completing the project.
3	Memphis Clock Project	Completing a product analysis of an existing Memphis product. Design specifications. Designing the clock. Making & decorating the clock.

4	Designing Our Tomorrow Designing for the Elderly Project	Task analysis using simulation gloves and glasses to role-play what it might be like to be elderly. Ideation and designing. Prototyping using card. Improving the prototype. Creating a model using MDF. Final prototype.
5	Sensors & Programming Project	Soldering a sensor. Learning how sensors work in the world around us. Programming the sensor. Creating the prototype. Creating a poster explaining and evaluating the final prototype.
6	Biomimicry Plywood Photo Holder	Collecting images of plants. Sketching the plants. Finding abstract shapes in the plants. Creating plywood formers in the shape of abstract lines. Constructing the frames.
7	Designing Our Tomorrow 'Asthma Challenge'	Learning about the problem of infant asthma. Role-playing and learning about the wants and needs of various stakeholders. Developing design ideas. Creating the designs. Evaluating the designs based on stakeholder wants and needs.
8 (most feminine)	E-Textiles LED (light emitting diodes) Pencil Case	Creating a mood board of different pencil case designs. Learning about circuits. Creating design ideas and competing WWW/EBI for each. Creating final design.

4 DISCUSSION

4.1 Existing Understandings of Masculinity and Femininity

Given that the extant literature argues that masculinity and femininity are not fixed and depend on the context in which they are being observed, it was necessary to gauge what masculinity and femininity looked like at the school the participants attended. At the start of the interview, the participants were asked to articulate their understanding of masculinity and femininity and what sorts of characteristics and behaviours were evident in dominant (popular) masculinity and femininity at their school. The group's definition of masculinity was 'a guy' who was muscular and tough. For femininity, it was having long hair, softness, wearing dresses and being 'girly'. No reference was made for being a 'girl' when describing femininity. When describing the qualities of popular masculinity, the participants detailed being good at rugby, having a specific hairstyle, being cheeky in lessons, being tough, and possessing a big personality. Toughness and sporting prowess as markers of hegemonic masculinity have been discussed and reflected in the literature (Paechter & Head, 1996; Connell, 1989; Paechter, 2003; Clark & Paechter, 2007), as well as displaying disruptive behaviour in the classroom (Dixon, 1996, 1998; Anglim, 2021; Francis, 1999; Connell, 1989). For defining dominant femininity, the participants described a specific popular girl in their year, which was being sporty (playing netball and hockey, specifically), being academic, being funny, and if you were an 'older one', then wearing make-up and being ‘girly’ were also important. Indeed, being good at sports, girly, funny and academic speaks to the pressure girls face for needing to 'have it all' through carefully balancing elements of masculinity (sporting ability) with femininity (Skelton, 2010), each aspect of this identity requiring time and effort to achieve (Ringrose & Walkerdine, 2007; Raey, 2001). The knowledge of the participants' existing understanding of masculinity and femininity and the hegemonic forms of each was essential to establish before exploring their perceptions of masculine or feminine tasks, artefacts, and projects in D&T.

4.2 Masculinity and Femininity in D&T

Indeed, it is inevitable that the participants' perceptions of specific tasks in D&T as either masculine or feminine are entirely subjective and were informed by their personal experiences of D&T. Nonetheless, the participants had clear ideas and opinions as to which tasks were masculine, feminine, or neutral. For example, when creating their list of D&T tasks, participants perceived any task with programming or electronics as masculine, which aligns with much literature surrounding girls' perceptions of Technology and computing (Coulter, 2023; Weibert et al., 2014). Likewise, any tasks involving textiles and fabrics were perceived to be feminine. Further, while discussing project outcomes (Table 1), the participants made distinctions and generalisations between masculine and feminine project outcomes, with one of the opening statements made during the activity being, "*Anything to do with textiles is feminine"*, with the rationale being that only two boys were doing it in Year 9, whereas robotics and electronics were generally masculine. However, contradictions arose here in their earlier statements surrounding D&T tasks, and their perceptions of outcomes and projects in Table 1 and Table 2. In fact, while perceiving any task to do with programming and electronics as masculine, we can see that many of the outcomes and projects that involve these are not always perceived as masculine, and the textiles pencil case is neutral in Table 1. The micro:bit and e-textiles were not associated with masculinity, despite involving coding/programming and electronics. Perhaps the strong associations between femininities and caring (the sensor project was for a baby product and a plant feeder) and femininities and textiles (the e-textiles pencil case) overpowered the perceived masculinity of programming or electronics.

Moreover, the literature suggests that combining an intensely feminine material with a strongly masculine one leads to a neutral product and encourages engagement with opposing gendered materials. For instance, e-textile projects have successfully challenged stereotypical attitudes towards creating products using textiles (associated with femininity) or electronics (associated with masculinity). For example, Coulter (2023) found that using e-textiles in a longitudinal group-working cross-curricular STEM and design challenge could degenderise the pupils' thinking, especially towards textiles. Similarly, Weibert et al. (2014) found that boys and girls could engage equally using e-textiles and sewable programmable components, reducing gender-stereotyped behaviour. It was the case in the current study that the participants perceived the e-textiles pencil case to be quite close to neutral on the scale of masculine to feminine artefact outcomes (Table 1), though when the e-textiles project process was considered (Table 2), it was perceived to be the most feminine project out of all the projects. Interestingly, this demonstrates that thinking about the project processes involved can be perceived as more or less feminine/masculine than the resulting artefact, or the act of completing a task associated with the project, i.e., a pencil case is neutral (Table 1), but sewing and using textiles, and the pencil case project process (Table 2), is perceived as feminine.

Both Coulter (2023) and Weibert et al. (2014) emphasised the importance of scaffolding projects that focused on presenting problems for children to solve using e-textiles and programming as part of a material solution, with a focus on pupil creativity and ownership as opposed to emphasis on producing polished, identical end outcomes. However, the participants did consider projects and outcomes that focused on solving problems to be gender-neutral, which supports the importance of scaffolding and encouraging a problem-based learning approach. Interestingly, the participants rated project processes that focused on the practical making aspects as more masculine than those that focused more on designing, prototyping, iterating, and evaluating. For instance, the two projects that were considered most masculine were the electronic memory game and the pine trinket box, both of which had minimal designing activities and instead required pupils to learn about resistor values or complete an isometric drawing. Both projects were taught this way in Year 7 at the participants' school.

The participants perceived problem-solving in D&T to be a neutral task during the interview discussion, and projects and outcomes that encouraged or demonstrated open-ended solutions (such as the Designing our Tomorrow projects, or the sensors) were also considered neutral or feminine. However, when thinking about tasks in D&T when everyone was making their own individual/unique project in D&T was perceived as masculine. Everyone following instructions to make the same thing was perceived as feminine. This is somewhat contradictory, given that problem-solving projects tend to involve everyone making their own individual/unique project.

However, the participants frequently discussed and referenced the confidence and arrogance of the boys in their D&T classes and held firm beliefs that boys wanted to make products for themselves, regardless of the project brief. Indeed, the perception of confidence within the D&T workshop was perceived to be masculine, which reflects findings of the existing literature (Dixon, 1996; 1997, 1998), despite the elapsed time between the literature and this study. Further, this perceived masculine confidence was met by irritation by the participants, who were dissatisfied with boys' domination of the D&T workshop, again aligning with the literature on this topic (Dixon, 1996; 1997, 1998). This frustration appeared to stem from the fact that the participants particularly enjoyed the prospect of creating and coming up with their design ideas, with some of the projects in Tables 1 and 2 sparking excitement. Similarly, unlike suggestions from the literature (Dixon, 1996; 1997, 1998; Anglim, 2021) and the author's pre-existing assumption, the participants enjoyed the subject's practical elements.

However, while the participants expressed their enjoyment of practical tasks working with materials such as wood, metals, CAD/CAM, and plastics, they believed that their teacher, whom they identified as being highly masculine, did not perceive them as being capable of completing specific practical tasks to do with these materials. For example, while discussing using saws to cut wood or using the laser cutter, the girls explained how their male D&T teacher would often get a boy to help them or complete their work without the girls wanting this to happen. Further, the girls explained that they believed their teacher did this because he thought they did not know how to do it properly, which they found frustrating. In this instance, rather than allow them the opportunity to complete the task on their own, their project is handed over to a boy to complete. Likewise, by removing the participants' opportunity to persevere with their practical tasks, they could not build familiarity with the procedure, which, if left to complete it independently, could have built their confidence with the task. Interestingly, the girls did not categorise many other tasks and activities involving material manipulation as masculine. For example, working with wood, metals, plastics, CAMs, 3D printers, sanding, gluing, and using screws were all deemed neutral tasks. The participants' perceptions of masculine and feminine tasks illustrate how careful teachers must be when implicitly implying that girls cannot complete a specific task.

In conclusion, according to the participants in the context of this school, masculinity and femininity have distinct identities, with certain qualities such as appearances, academic abilities, sports played and mis/behaviours in class being essential factors in defining such status as masculine or feminine. Likewise, in the D&T classroom, specific tasks, product outcomes and types of projects are also considered masculine or feminine. In this case, the participants considered that confidence in the D&T workshop and engaging with a more experimental approach in D&T were masculine, and focusing on solving problems and considering the needs of others were feminine. In contrast, those that focused on skill building, rather than design thinking/problem solving were more masculine. As teachers, we must understand the gender rules within the specific context we are working within to ensure projects are as inclusive and appealing as possible. Indeed, for D&T to be genuinely inclusive, projects should be problem-focused instead of skills-focused, and teachers should be cautious about asking boys to help girls with their work when assuming that girls do not enjoy the practical elements of the subject.

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Do No Harm 2.0

David Spendlove, University of Manchester, david.spendlove@manchester.ac.uk

ABSTRACT

Previously, I have proposed that the current incarnation of England's Design and Technology, version 1.0, is outdated and requires a new manifestation in the form of Design and / or Technology 2.0. Within this context a starting position for 2.0 subsequently acknowledges that on any given day students across the globe, who have adopted a form of version 1.0, are potentially doing more harm than good. Students are being 'processed' into a capitalistic consumption and production mode of thinking through contrived processes of generating 'products' under the pretence of solving problems. In this paper, a challenge to the community, I draw on the medical Hippocratic oath of "Primum non nocere", known as "Do no harm" and consider the pragmatic, ethical and philosophical implications of adopting this principle as a central feature of 2.0.

In this paper I will also consider an alternative discourse for the current pervasive materialistic 'outcomes' in the context of 'do no harm' through challenging the anti-democratic, exploitative, perpetual rapid growth-oriented capitalist ideologies that manifest within 1.0 as 'artefacts', driven by self-fulfilling 'needs and wants'. Consequently, learner accountability, liability and culpability are located as central features of a 2.0 'activist' strategy that is earth and sustainability centred. A 2.0 mantra of 'do no harm' consequently aligns with UNESCO's commitment to equity and transformational Education Sustainable Development through empowering lifelong learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity.

Keywords 2.0, Hippocratic, Sustainable.

1. INTRODUCTION

Following the interruption of the Covid pandemic, I once again visited a design museum, as I have done many times previously, looking forward to being intellectually stimulated by the creativity and innovation of past designers. However, something was different, as instead of looking at the 'products' through my usual lens I was struck by the celebration of overconsumption, environmental damage and naïve vanity being celebrated in the name of design. This moment of cognitive dissonance was not however new as this was something that had pervaded my thinking for some time, in that it linked to my reoccurring questions for the

Design and Technology community as to whether 'the subject' is potentially doing more harm than good?

A starting position for this short essay therefore acknowledges that on any given day students, across the globe, studying a form of 'England's' Design and Technology education (which I will refer to as version 1.0) are potentially doing more harm than good. They are potentially being processed into a capitalistic consumption and production mode of thinking through contrived processes of generating 'products' under the pretence of solving problems, product design and manufacturing. Inevitably there are numerous and potential justifiable counter arguments to such a provocation. However, it is essential that we examine whether the existing default mode of 1.0 and the consequential damaging impacts on both the individuals and the environment can legitimately justify the means.

In asking the question above, it is within a broader existential context where in reality (and my personal view) the current model of Design and Technology (version 1.0) in England is now so diminished and damaged that it is difficult to envisage anything more than a modest recovery, given that the majority of infrastructure that saw the organic evolution of the subject has been both dismantled and disenfranchised (Spendlove, 2022). In many respects this can also be regarded as positive, in that the next iteration of the subject cannot be built on the same model from which the subject originated, given the local education authority networks, advisory services and initial teacher education provision within universities, that contributed to research, curriculum development, accreditation and professional learning for teachers have increasingly become marginalised and replaced by new structures and organisations.

Therefore, in positing my question of the potential and significant unintended consequences of Design and Technology, extends my journey of thought and publications questioning the existing 1.0, and speculating on an alternative iteration of Design and Technology, in the form of Design and or Technology 2.0 (Spendlove 2017a; Hardy 2020; Hardy and Norman 2021). This follows and builds upon previous considerations and theorisation about the contradictions, coercion and collusion (Spendlove 2013) within the subject and the limitations of the 'thinking' elements (Spendlove 2017b), activist opportunities (Spendlove 2022a) and future sustainability (Spendlove 2022) of Design and Technology education. Indeed, the origins of this journey start from England's superseded national curriculum from 2007 and in particular the statement of importance where children were expected to 'intervene to improve the quality of life' (Spendlove 2008). Whilst many may have glossed over the 'statement of importance', driven by a preoccupation to exemplify the subject norms of consumption and production, I have often been struck, and have written (Spendlove 2008), about both the profoundness, and the opportunity of the challenge that was set, when considering what intervention 'to improve the quality of life' might look like and how it may paradoxically challenge many of the existing beliefs and values that the existing version of Design and Technology was built upon.

2. THE CHALLENGE OF CONSUMPTION AND PRODUCTION

As we come to the end of the first quarter of the 21st century, you can choose any number of avenues by which to decide how the current iteration of Design and Technology got to where it is today. Within this context, over time and across the last half of the previous century 'the subject' and historical incarnations has adapted from predominantly a craft apprentice and manufacturing oriented model to increasingly include a more diverse range of materials, processes and technologies shaped by examination boards and shifting political priorities. Across this period has also been a consistent theme of production, typically artefacts, often legitimatised both as means of aspiration (taking something home) and mode of assessment and frequently endorsed by the contrived concepts of 'needs and wants' (DfE, 2013). Such justifications have however increasingly become difficult to acknowledge as whilst considering the indefensible material waste within the subject, it also confirms the implicit message of the naive legitimising of consumption of materials on the basis of contrived justifications. As such Design and Technology has been built upon the excesses of unethical, hierarchical, capitalist principles of production and consumerism which thrive on the evolutionary flaws of gratuitous accumulation and consumption.

Previously I have challenged the assumptions that designing is a conscious, intuitive and rational act, positing that as design 'thinkers' we are prone to cognitive limitations and cultural distortions. In this context a blind spot remains particularly within in an education system where the means to notional 'successes' within existing subject configurations is demonstrated through adherence to, or giving the impression of, reproduction of capitalist, consumerist and colonialist view of the world. Apple and Weis further identify how schools exemplify such complex structures through which social groups and activities 'are given legitimacy and through which social and cultural ideologies are re-created, maintained, and continuously built' (1986 p.9). Therefore, our existing culture of production and consumption is legitimised and reinforced through the cultural norms of schooling. It is therefore only through disruption of the existing mode of Design and Technology that an opportunity exists to confront and critique our relationship with production and consumption in order to challenge preconceptions of power and influence.

Ultimately and ironically, we therefore have an education system, and specifically with the current mode of England's Design and Technology, where the means to 'success' is also the means to long term failure, as in 'performative success' is through the reproduction and acceleration of capitalism, class systems, and climate crisis. Yet the moral imperative for the broader 'design' community has long called for a commitment to the broader social, environmental, financial, and ethical challenges (Papanek 1985). As a consequence, we have a subject disconnected from the 'real world', caught in a mobius strip like continuum of misalignment that neither connects with or reflects the major challenges of society whilst maintaining its own self-perpetuating eco system of production and consumption. Likewise, the teaching profession itself needs to be 'educated and politically astute' (Sachs, 2003), as teachers are uniquely placed to 'see first-hand' the inequity and economics of poverty played out in their classrooms and local communities. More specifically, teachers, and in the context of 1.0, need to be aware of their presumably 'unconscious' reproduction of the broader neoliberal (Giroux, 2004) project that constrains rather liberate their students.

The challenge is therefore an economic, social, cultural and environmental one, manifested through a crisis of 'design', in which it has taken only a century to establish a dependency through the selling of an illusion based upon consumption, mass production, aesthetics, industrialism and ownership. The consequence of dependencies engrained within society and reinforced through

1.0 are now apparent and unsustainable and where future iterations of ‘design’ education cannot be passive (Micklethwaite, 2019).

3. DO NO HARM 2.0

Right here. Right now. This is where we draw the line (Thunberg, 2019).

In attempting to reconceive what an alternative vision of the subject should be for 2.0, the adoption of an equivalent of the Hippocratic oath, which when translated from its Latin expression, primum non nocere, as “above all do no harm’ (Ashton 2004), is proposed. Whilst the origin of the Hippocratic oath is open to contention (Smith 2005), the positing of ‘do no harm’ as a set of ethical value and moral conduct for 2.0 is both desirable yet inevitably simplifies a complex topic that is far from resolved in the medical field.

In his book ‘Do no harm’ (2014), the brain surgeon Henry Marsh highlights the dissonance of navigating the fine line between seeking to improve the quality of an individual’s life and the potentially fatal consequences of getting such decision making wrong. The parallels, albeit not in such dramatic immediacy, with the argument being made within a 2.0 context, should therefore be clear that contradictions within 1.0 are potentially contributing to cumulative and fatalistic consequences through poor decision making.

However, whilst ‘do no harm’ gives the appearance of a desirable guiding principle, ultimately it is insufficient to guide the practice and general ethics of medical professionals (Lasagna 1967) as the limitations are exposed by complex ethical problems. Equally whilst the Hippocratic oath may serve as an important reassurance to patients and epitomises the values and ethos of profession, in reality it is open to interpretation, inconsistencies and contradictions (Weising 2020).

The Hippocratic oath nevertheless provides an underlying guide and symbolic set of principles that provides a challenge to consider what would be the equivalent to such an ethical and guiding set of principle within 2.0? Unsurprisingly such a challenge is far from easy, made all the more difficult when the prevailing discourse, governance and structures contribute to a climate of negligence and ‘unintended’ consequences through reinforcement of culture of compliance and consumption within 1.0.

Adopting a ‘do no harm’ philosophy does however offer an alternative discourse for the current pervasive materialistic ‘outcomes’ that promotes anti-democratic, exploitative, perpetual rapid growth-oriented capitalist ideologies that are manifest within 1.0. Equally ‘do no harm’ questions the legitimacy of ‘artefacts’, driven by self-fulfilling ‘needs and wants’ and offers a justifiably sustainable future 2.0 version of the subject. Consequently, learner accountability, liability and culpability are located as central features of a 2.0 ‘activist’ strategy that is earth and sustainability centred. A 2.0 mantra of ‘do no harm’ consequently aligns with UNESCO’s commitment to equity and transformational Education Sustainable Development through empowering lifelong learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity (2019).

Inevitably the simplistic adoption of 'primum non nocere' quite deliberately generates more questions than answers as to where the ethical and moral lines are drawn. Yet this is precisely what needs to happen as teachers and students need to be questioning under what circumstances, if ever, it is legitimate and justifiable to embark on activities that ultimately have negative social and environmental consequences. In such circumstances the challenge is in the examination of whether the educational gain outweighs the magnitude of the ethical and ecological ramifications. Indeed, this reflection alone, of the cost benefit analysis, offers potentially greater educational value than much of what occurs in 1.0 and exposes some of the fallacies upon which the subject has become dependent on to legitimise existing practice.

In drawing parallels with education and specifically 2.0, similarities with the life and death matters of the medical profession may appear facile. Yet to adopt such a position fails to acknowledge the significance of education or to recognise that Design and Technology in its current and future iterations is far from neutral and represents a place of social, political, theological and cultural ideologies manifested as an entitlement within the curriculum. As such increasing our expectations about what happens, and importantly in the case of 'do no harm' what doesn't happen, becomes of critical importance.

4. CONCLUSION

I have previously called for a 2.0 version of Design and or Technology as both a theoretical opportunity to examine 'what if', but also the means to take action. The starting point being in this context to recognise that the 1.0 version of the subject is now outdated, operating on a set of redundant values and principles that may have been legitimate in the previous century, but which currently sit uncomfortably in the context of increasing inequalities and climate crisis.

In previous provocations and challenges to the community, a starting position is that Design and or Technology 2.0, within an education context, should be activist orientated and accordingly, it is not a choice whether to be activists on not, it is the extent and direction of the activism that is for consideration. Furthermore, a further dimension of 2.0 is the prioritisation of a 'Design Thinking' mode that foregrounds and acknowledges inherent cognitive limitations when making decisions.

My third dimension for 2.0, as highlighted within this short essay, emerges from the concerns of an outdated default 'modus operandi' of consumption and production that negates to acknowledge the damage and limitations within 1.0. Accordingly, the prevailing western economic model, premised on sustained growth with finite resources fuelled by exploitation of the cognitive flaws of consumerism and consumption, is exemplified through populist manifestations of the subject. This 'challenge of the commons', where individuals neglect the well-being of society in the pursuit of personal gain, leading to over-consumption and ultimately depletion of the common resource, is to everybody's detriment (Boyle, 2020) and is now very apparent. Adopting an equivalent of the Hippocratic oath and a commitment to consider 'primum non nocere', therefore offers the opportunity and expectation to contemplate the educational and environmental cost benefit analysis of future iterations of the subject.

The reality is that a 'Design and or Technology education' has significant potential to contribute to shaping a 'better' society and to meet the 2007 national curriculum ambitions of intervention 'to improve the quality of life'. It offers a powerful context to question assumptions about civil liberties, political and economic power, society, poverty, media, consumption and wealth as each is implicit and embodied within the pedagogy of the teacher and the decision making of the students. 2.0 therefore challenges many of the preconceptions that underpin everyday actions within 1.0 and fundamentally questions the legitimacy and premiss of capitalist consumption and exploitation which do more harm than good.

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Girls' Technological Knowledge

Ulrika Sultan, Örebro University, ulrika.sultan@oru.se

ABSTRACT

This study investigates technological knowledge among 13-14-year-old girls at a technology-focused summer camp using a Science and Technology Studies (STS) lens. As they are already interested in technology, they attend the camp out of genuine interest instead of ones to become interested. The girls' expressions of technological knowledge are aligned with societal norms associating technology with hands-on engagement and activities, solidifying their self as belonging in technology. While the camp introduced certain gendered assumptions through "girlified" tasks, the girls wished to transcend these stereotypical activities. They wanted to broaden their technological interests beyond the confines of gendered expectations. Actor networks and external recognition influence their technological knowledge, often motivating their engagement in technology. During an interview, the girls voiced dissatisfaction with existing technology education, mentioning uninspiring teaching methods, outdated materials, and a focus on theory. The girls were critical of the technology education they encountered and emphasised the value of practical learning and a longing for real-life applicable skills. Despite some finding technology classes engaging, low self-confidence in comparison to boys emerged, possibly due to teacher expectations. Their inclination towards practical experiences highlights the importance of a well-rounded learning approach. Implications for school technology education curricula underscore the significance of blending theory with practical application to keep technical girls engaged. By embracing girls' perspectives, educators can craft initiatives that resonate with their interests, rejecting the need for gender-specific content. These insights challenge the stereotype that technical knowledge is gender-bound, recognising that girls' genuine interest is an asset.

Keywords: Technological Knowledge, Technology Education, Technical Girls, Girlification, STEM camp

6. BACKGROUND – GIRLS' TECHNICAL KNOWLEDGE

Even if there is evidence of an existing difference in technical interest between girls and boys at the end of primary school (de Vries 2005; Mawson 2010), Adenstedt (2018), when comparing girls' and boys' interest in developing technology knowledge, found no significant difference. Other studies investigated various aspects of technical knowledge, including girls' attitudes towards technology (Niiranen, 2016), self-efficacy beliefs (Pajares & Miller, 1994), educational experiences (McLain et al., 2019), career aspirations (Klapwijk & Rommes, 2009), and the impact of societal and cultural factors (Cheryan et al., 2015; 2017; Kim et al., 2018) on their engagement with technical subjects. Archer et al. (2015) and Arifin Mim (2019) aimed to identify barriers and challenges that girls face in developing and expressing their knowledge and skills within STEM (Science, Technology, Engineering and Mathematics), as well as effective strategies to overcome these barriers. Others like Gagnon and Sandoval (2020) and Sultan (2022) focused on examining the role of various educational environments in fostering girls' technical knowledge, such as summer camps. Moote et al. (2020) explored the influence of different interactions on girls' motivation, learning outcomes, and engagement in technical fields. Research regarding different aspects of girls' in technology often aims to identify effective strategies and interventions to bridge the gender gap and inspire girls to pursue and excel in technical fields, ultimately fostering a more diverse and inclusive landscape in technology-related domains (e.g., Adebimpe, et al., 2011; Alam, & Tapia 2020; Blickenstaff 2005; Mammes, 2004). What links the research mentioned is the willingness to understand the factors influencing girls' engagement, participation, and achievement in technical subjects and fields, not uncommonly focusing on how to make girls interested in learning and future work.

Additionally, Archer et al. (2013) investigated the effect of gender stereotypes, cultural norms, and representations on girls' perceptions of STEM subjects and their identification with related career paths. Lane and Sorby (2022) and Sultan et al. (2019) have highlighted the importance of promoting inclusive and supportive learning environments that encourage the development of technical knowledge. This may involve learning in and outside the classroom.

7. METHODOLOGY

This section describes the camp, the girls attending, the theoretical framework, data collection and ethical principles.

7.1. Empirical setting

The camp organisers were a national but municipality-based technology association, and the camp aimed towards girls aged 13-14. The summer camp is a yearly recurring event that spans three consecutive days and offers various technology-related activities. The venue for the camp included an upper secondary school known for its industrial and educational programs, as well as the premises of a national technology association. The decision to create a camp exclusively for girls was motivated by the intention to provide an environment where girls could feel at ease and receive support without competing with boys for attention, resources, or knowledge. The camp activities included computer coding, welding, laboratory work, design elements and 3D printing, laser cutting, and electronics. The camp organisers aimed to promote technological literacy and encourage girls to pursue educational programs focusing on technology. The main aim of the camp was to spark interest and enthusiasm among girls for a future in technology.

7.2. The girls

The camp accommodated 100 participants who identified as non-binary individuals or persons identifying as girls. All participants will in this paper be communicated as "girls". These participants came from diverse socioeconomic backgrounds and had varying levels of prior technical experience, ranging from beginners to highly skilled, depending on the specific content and context. However, a shared factor among them was their interest in technology, and they voluntarily applied to attend the camp.

7.3. Theoretical standpoint

Science and Technology Studies (STS) is a field that examines the interrelationships between science, technology, and society. It provides a framework for analysing how technology is shaped by social, cultural, political, and economic factors and how it, in turn, influences society. When applied to the analysis of technological knowledge, STS can offer insights into the broader context in which knowledge is produced, disseminated, and applied. STS emphasises the social construction of technology, highlighting that its technical aspects do not solely determine technological knowledge but are also influenced by societal values, norms, and power dynamics (e.g. Sismondo, 2011). By employing STS approaches, one can examine the social processes through which technological knowledge is generated, validated, and legitimised. An STS analysis of technological knowledge can involve studying various dimensions, including social construction Klein & Kleinman (2002), actor networks (Sayes, 2014), and technological artefacts (Pinch & Bijker, 1984). These three dimensions are explored in this study since they can be considered part of the camp.

STS also explores how social factors, such as cultural beliefs, historical contexts, and political agendas, shape gender and technological knowledge (e.g., Schiebinger, 2014). Using this as a tool for analysis can reveal how girls have different understandings and perspectives on technology. Exploring the actor network involved in producing and disseminating technological knowledge involves tracing the relationships and interactions in this study, it is, for example, schools, teachers, and legal guardians. STS also examines the materiality and design of technological artefacts and systems and how they embody specific forms of knowledge. This analysis can uncover technological solutions' assumptions, biases, and values. By applying STS frameworks and methodologies, researchers can gain a comprehensive understanding of how technological knowledge is situated within broader social contexts (Schiebinger, 2014). This approach helps to reveal the complexities, uncertainties, and values that shape technological development and use, enabling critical assessments of technological knowledge and its educational implications.

7.4. Focus group interview

On the last day of the camp, a focus group interview took place. This interview involved a diverse group of girls who had collaborated in, by the organisers, a pre-decided group throughout the three-day program. Participation in the interview was voluntary. The interview followed a semi-structured format, with questions generated from the researcher's observations during their active participation as an observer over the three days. The focus group session lasted approximately 30 minutes and included nine girls. The semi-structured approach of the interview allowed for probing and follow-up questions. This allowed the girls to provide more details and context about their experiences. This method is rooted in established research practices, similar to semi-structured interviews that encourage a thorough exploration of participants' viewpoints (Galletta, 2013; Krueger & Casey, 2000). Through the discussion and interaction among the girls, the researcher aimed to gain insights into their discourse, dynamics, and technological knowledges. This approach provided an opportunity to explore the girls' experiences and perspectives within the camp setting, allowing for a richer understanding of their engagement with technology and their social interactions during the camp. On the other hand, there can be possible distortions in the data due to the interview being a group discussion with a comparatively large group of girls who presumably hardly know each other.

The interview was transcribed and analysed through the lens of STS. The analysis process went through three phases. First, it was coded from Social construction, Actor-networks, and Technological artefacts and systems. The second phase was to identify and generate preliminary codes for statements related to the motioned categories in the transcript. Next, statements were identified as containing words and phrases describing the categories.

Table 1.
Example of phase three - words and phrases used to identify STS,

Code	Examples
Social construction	Girly, creative, boring, fun,
Actor-networks	Dad, teacher, home, school, class, friends
Technological artefacts and systems	Computer, mechanical, programming
	"How things work." "Push a few buttons, and something will happen."

The words and phrases stand for the communication of the identified themes. These themes are organised based on the types of technological knowledge expressed. Under each theme, summarising analysis and quotes from the participants' responses are included to support and illustrate their perspectives.

7.5. Ethical principals

Adhering to ethical principles, in compliance with the guidelines set by the Swedish Research Council (2017), the study ensured informed consent by providing participants with information about the focus group interview's purpose. Participants were informed of their right to withdraw at any time, and those girls who chose to engage actively were granted the opportunity. Consent was obtained from both participants and their legal guardians, with anonymity guaranteed. Data usage complies with the General Data Protection Regulation (GDPR) regulations, ensuring secure storage and protection.

8. RESULTS

The following section presents the analysis results using the three STS categories: 1. Social construction, 2. Actor- Network and 3. Technological artefacts and systems, to express technological knowledge.

8.1. Girls' expressing technological knowledge in forms of social construction

The girls' technological knowledge perspectives reflected a societal norm of associating technology with hands-on activities and creation, contributing to a sense of identity as doers and makers. However, the camp also had certain assumptions since they made some activities girlified. With girlified means taking non-gendered activities and making them "girly". In this case by organisers adding glitter or pink to the artifacts presented as possible ideas. During the interview, the girls expressed a desire to move away from these gendered activities, suggesting they wanted to explore beyond stereotypical pursuits. The motivation for participating in the technology camp stems from multiple aspects. One of the reasons is a critique of traditional school technology education as not being good enough, suggesting that the girls may find the camp as an alternative and more engaging learning environment. Additionally, they indicated an aspiration for academic success and future studies. Furthermore, they were eager to meet new friends who share a common interest in technology, highlighting the social aspect of the camp and the opportunity to connect with like-minded individuals.

8.2. Girls' expressing technological knowledge in the forms of actor-network

When asked the girls perceive themselves as having technical abilities, although they may find it difficult to acknowledge this openly to others. They reflect their technological knowledges in the eyes of others. One girl talked about a father inviting her to participate in everyday activities, and another spoke about the feeling of belonging and non-belonging a teacher can give in the classroom. Comparisons with others often shape their self-perception. The recognition of being seen as technical by others motivated their participation in the camp. These girls frequently encounter inquiries about technical matters both at home and in school, and they often demonstrate their problem-solving skills by successfully addressing these inquiries.

The girls expressed their dissatisfaction with technology education, describing it as bland and unappealing. They attributed this to a range of factors, such as incompetent teachers, outdated or broken materials in school, and a focus on theoretical aspects rather than hands-on activities. They emphasised the importance of practical work and expressed a desire to learn relevant skills they can apply in real-life situations. However, there were also some positive comments. Some girls indicating their interest and eagerness to spend more time on technology-related activities in school. Additionally, they perceived women teachers as more enjoyable or thorough, suggesting a positive influence of women role models in the field of technology education.

The interviewees articulated tending to downplay their capabilities and exhibited low self-confidence, even though they generally believe they are better than the boys at technology. This is likely influenced by the expectations set by teachers mentioned in the interview, which the girls felt portrayed girls as less technically savvy. As a result, they often compare themselves to boys and feel inferior on an individual level. However, when stimulated by their peers at the camp, the girls exhibit a strong sense of technical identity and proudly identify themselves as technical.

8.3. Girls' expressing technological knowledge about technological artefacts and systems

During the focus group interview, it was clear that several girls had a pre-existing interest in and fascination with technology before applying to the camp. This was reflected in the response of one girl who stated being good at computers and being a problem solver if something is wrong with the computer. The girls also expressed interest in soldering and mechanical work. The girls strongly preferred practical and hands-on experience, emphasising the importance of learning how things work and acquiring knowledge that has practical applications in the real world. They did not perceive only writing about technology as highly valued. The girls expressed a desire for improved technology education that focuses on both knowing and doing.

9. DISCUSSION

Using three STS categories, this study examines how nine girls aged 13-14 expressed their technological knowledge when taking part in a summer camp for girls interested in technology. Even though the interview has a limited scope, it can still provide insights by using the three STS categories. It can also be seen that the camp's design could influence the girls' attitudes negatively and positively more than what the results show. However, since I lack questions exploring this possible insight, I will not discuss this. What can be seen as extra interesting is the girls' pre-existing interest in technology. They are girls who do not need to become interested but rather attend the camp because of interest, which is an unusual scope of research. The focus group interview highlighted the girls' fascination with technology before camp participation. The motivation underlying the girls' partaking in the technology camp is multifaceted. Firstly, their critique of conventional technology education. Secondly, the camp's actor-network dimension is noteworthy. The girls are enthusiastic about forming friendships with peers who share their technological passions, underscoring the importance of communal engagement and the potential for connecting with like-minded individuals.

Girls understanding about technological knowledge aligns with a prevalent societal norm associating technology: hands-on engagement and activities, solidified their self-identity as being technical. However, the technology camp they attended also introduced certain socially constructed assumptions by including "girlified" tasks, incorporating stereotypically feminine elements like glitter and pink. Interestingly, during interviews, the girls expressed a desire to transcend such gendered activities, signalling an aspiration to broaden their technological interests to encompass a broader range of non-stereotypical pursuits. This can be because they already identify and align with what is generally seen as technology and belonging in a technical setting. They need not be persuaded into technology by "girlified" activities. By girlified I mean the manifestation of the general misconception that girls need special activities or colours to engage in technology. We can compare it to believing girls can only become interested in driving Formula 1 or playing rugby or football if the car, balls, track or fields are pink. Girlification can be off-putting for girls already interested in this kind of activity.

When asked about their interest in technology, the girls saw themselves owning technical knowledge, though they might struggle to admit it openly. Their self-perception of technological knowledge is often influenced by how others perceive them. For instance, one girl mentioned her father's involvement in her daily activities, while another discussed the impact of teacher attitudes on her sense of belonging in the classroom. These external comparisons shape their self-identity, with recognition from others as technical motivating their participation in the camp.

The girls expressed dissatisfaction with their current technology education, finding it uninspiring. They attributed this to inadequate teachers, outdated materials, and a focus on theory over hands-on experience. They stressed the importance of practical learning and a desire to get applicable skills for real-life scenarios. A thing encouraged in the curricula but maybe not to the practical extent the girls wished for. Despite this critique, some girls found going to classes engaging and wished for more scheduled time learning technology. They also saw women teachers as more enjoyable and thorough, indicating the positive effects of teacher role models in technology education. This is interesting since none of the girls mentioned their mothers as inspiration or companion when engaging in technical activities. Even if they believe they outperform boys in school, the girls tend to downplay their abilities and exhibit low self-confidence in class, possibly due to some teacher expectations of girls as less tech-savvy. This behaviour is in line with what is noted in Sultan (2022). Consequently, girls expressed to feel often inferior when comparing themselves to boys.

9.1. Implications for school technology curricula

The girls showed a strong inclination toward hands-on, practical experiences. They placed significant value on understanding the inner workings of technological components and gaining knowledge with real-world relevance highlighting a multifaceted wish for technological knowledge in school. Their ideal technology education combined theoretical insights with tangible applications, reflecting a preference for a well-rounded learning approach. What emerged notably from the data was the girls' belief that their interaction with the subject matter significantly shaped their sense of belonging in the realms of technology.

Empowering technical girls through a balanced blend of theory and practice in technology education does not just engage them – it equips them to navigate the intricate realm of technology. By bridging the gap between hands-on experience and reflective thinking, educators provide girls with the tools to grasp technology's multi-dimensional aspects. These insights, echoing findings by Mawson (2010) and de Vries (2005), underscore the value of contextual learning that aligns with individual interests. This perspective challenges the notion of using 'girlifying' content and recognises that technical competence is not defined by gender. By embracing girls' perspectives and experiences, educators can craft initiatives that resonate with girls and steer clear of the pitfalls of over-simplification that sometimes "girlified" activities turn out to be. After all, these young technical minds have already cultivated an identity within the technology landscape, making girlification counterproductive to their genuine interest.

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Using Movie-making to Visualise Pre-service Teachers' Perceptions of Technology

Ulrika Sultan, Örebro University, ulrika.sultan@oru.se
Barbro Bergfeldt, Örebro University, barbro.bergfeldt@oru.se
Erik Sjöstedt, Örebro University, erik.sjostedt@oru.se

ABSTRACT

This study uses a Bourdieusian framework to determine pre-service teachers' perceptions of technology before their engagement in any formal coursework of a technology education teachers preparation program. The analysis focuses on movies depicting three states of technological capital, revealing a duality between movie narratives and written reflections. These movies underscore a Western-centric perspective on technology, ethics, and social understanding. One film triggered self-awareness among students regarding smartphone use, demonstrating the potential of movie-making for prompting personal reflection. The study emphasises experiential learning through stop-motion movie creation. Moreover, aesthetics emerges as an avenue for students to articulate technological viewpoints, transcending conventional instructional methods. Aesthetic processes unveiled students' technological capital, although effective transformation centres on pedagogical adaptation. The study's methodological integration of storyboards and reflective components gives insights into students' evolving knowledge. The discussion shed light on technology education within the STEAM classroom. Findings show that by embracing students' perceptions and facilitating knowledge expression, educators can contribute to exploring technology's multifaceted role in the educational landscape.

Keywords: Technological Knowledge, Technology Education, Multimodal, STEM, Pre-service teachers, Teacher Education

1. INTRODUCTION

This article focuses on the education of pre-service technology teachers within a STEAM (Science, Technology, Engineering, Arts, and Mathematics) environment. In Sweden, technology education is an interdisciplinary field. Its purpose is to cultivate technological knowledge, skills, literacy, and a multifaceted understanding of technology's dimensions (The Swedish National Agency for Education, 2022). Despite sharing STE(A)M goals, the subject encounters challenges in defining its position within it, as it covers more than just technology (T) or engineering (E) alone (Sultan et al., 2022). Teaching technology education within an interdisciplinary STEAM framework poses challenges, as it not always interconnected regarding content or pedagogy, and typically STEAM subjects are taught in isolation from each other, with a primary focus on Science

(Allen & Matthews, 2016; Bertrand & Namukasa 2020; Bryan et al., 2015; Wickman et al., 2021) However, despite the growing popularity of STEAM education, there is limited empirical data and understanding of the challenges associated with its implementation and teaching.

Design has been identified as a promising element for unifying STEM subjects (Hallström & Ankiewicz, 2019; Lewis, 2006). Design can be recognised within technology education and be seen as a form of Art (Earnshaw et al., 2015). Integrating Art (A) with STEM further highlights the significance of design, creativity, and innovation in STEM learning (Bautista, 2021; Breiner et al., 2012; Liao, 2016). An aesthetic learning process serves as a representative method of learning, where symbolic expressions play a crucial role in representing perceptions of the world, emotions, or objects. However, learning processes can only occur when practical knowledge, reflection, and connections to prior experiences converge with newly acquired knowledge (Bergfeldt, 2022; Horh, 1998). Horh (1998) emphasises that aesthetic activities can be used to express the inexpressible. The learning experience evolves into an aesthetic learning process when it leads to knowledge.

2. BACKGROUND

Sultan et al. (2022) were inspired by the works of Hallström and Schönborn (2019), Herro et al. (2019), Hsu and Fang (2019) and Kelley and Knowles (2016) and proposed several strategies to enhance technology education in steam. Strategy one: Provide an extended timeframe for students to understand, engage with, and reflect on the task, enabling more profound and meaningful learning experiences beyond time limitations. Strategy two: Encourage students to create visual storyboards with a maximum of six frames before starting the movie-making process. This helps students articulate their ideas, make deliberate choices, and facilitates reflective discussions on their decisions and effective presentation strategies. Strategy three: Scaffold students in using artistic elements to convey their intended messages in the movie. Strategy four: Guide the students in selecting and highlighting relevant aspects that align with their concepts and subject knowledge, fostering a comprehensive understanding of technology within their creations. Strategy five: Create opportunities for students to verbally express their thoughts and reflections on the final movie. Encourage them to articulate their ideas, explain the creative process, and share the insights they gained throughout the project. This component enhances communication skills and nurtures critical thinking abilities.

By implementing these strategies, technology education within the STEAM framework can be enriched, providing students with valuable learning experiences and promoting interdisciplinary understanding. Therefore, this study aims to determine students' perceptions of technology before engaging in any formal technology education teacher preparation program coursework by adding the recommendations by Sultan et al. (2022).

3. METHOD

Our research approach for this study is descriptive. Descriptive studies serve as initial explorations in new areas of inquiry, providing valuable insights (Grimes & Schulz, 2002). We study pre-service teachers' perspectives and issues with teaching technology within a STEAM framework. The STEAM framework means taking an interdisciplinary approach but with the foundations of each subject's specific content knowledge. In our study, we employed a descriptive method to understand better the potential issues that arise when teaching technology education in the context of STEAM.

3.1. Empirical setting

This study takes place in a five-week course focused on technology education. Week one of the course was dedicated to exploring the concept of technology and involved readings on various topics, such as the philosophy of technology and didactics. However, before probing into the course readings, the students were tasked with creating a movie intended to capture their perspective on technology. The movie could revolve around an artefact, an idea, a system, or anything that reflects their personal views on technology.

The participants in this study were pre-service teachers at the university level. The course was situated in the third semester of their program, and the students were concurrently enrolled in compulsory courses covering subjects like biology, chemistry, physics, sustainable development, and technology. Aesthetic learning processes influenced our approach to teaching this course, emphasising the importance of creativity throughout the sessions. Technology education accounted for 7.5 credits out of the total 30 credits in the program.

3.2. Collecting data

We conducted an observational session that enabled us to gather information regarding the technological content depicted in the students' movies about technology. We were in the same room as the students during the observation throughout the session. We observed the movie-making, listened, gave guidance and made sure the students followed through with the tasks. We specifically targeted the students' written reflections. This descriptive research also aimed to identify challenges or issues related to technological content and the broader STEAM framework.

3.3. A Bourdieusian perspective

In examining the students' technological content, we drew inspiration from Bourdieu's conceptual framework of technological capital. A Bourdieusian perspective allowed us to identify the embedded technological knowledge within the students' projects and shed light on the presence of technology, technological content and knowledge in their choices. Bourdieu's perspective views technology as a product of invention, implementation, use, and cultural transmission (Bourdieu, 1979). Romele (2021) further elucidated the Bourdieusian perspective by demonstrating how technologies are intertwined with social and cultural dynamics involving classification, differentiation, exclusion, and discrimination. In other words, technologies extend beyond mere artefacts.

Bourdieu (1979) proposed three states of technological capital:

- Objectified: This encompasses all the technologies owned, used, or designed by individuals or groups.
- Institutionalised: It refers to certain actors or groups having access to and specific ways of using technological artefacts, while others may be excluded from such access.
- Embodied: Actors or groups possess the ability to permit or restrict the use of technological artefacts in particular ways.

To complement the concept of technological capital, we found it valuable to include some technology-specific definitions relevant to teaching and assessment practices. In Nordlöf et al. (2022), technical skills are defined as the technological knowledge of that things work but not necessarily knowing how they work. Activities like designing, creating, and making can exemplify these skills. Socio-ethical technical are in Nordlöf et al. (2022) defined as understanding the relationship between technology and the human world, encompassing knowledge about technology's impact and ethical considerations.

3.4. Stop-motion and movie-making

An instructional stop-motion movie-making session was given to support the determination of students' perspectives of technology and its application. Employing iPad hardware and the iMovie software, single-frame photos of an object were captured, revealing its shadow and prior position. This enabled gradual changes between frames by temporarily removing, altering, and returning the object to its original spot. Clay, a readily available and malleable material, served as the medium. While it demands time, as noted by Orraryd (2021), it offers valuable learning opportunities. In this study, the students were tasked with expressing their understanding of technology through the use of clay and stop-motion techniques.

The first step for the students was to create a storyboard about their chosen technology content. The second step was to make the cinematic story they wanted to convey. Examples of such technological stories included "Abdi's Apartment," "Love Is In The Rain," and "The Globe." It is important to note that these stories evolved and underwent changes throughout the production phase. The students gave each other feedback on their ideas between steps one and two. The third step was to make the movie. In the fourth step, the student group watched the films and orally presented their thoughts on the result. In the last session of the workshop, the students were asked to write an individual reflection about their work. The finished movies and the student's personal thoughts served as the data for our study, providing insights into the students' understanding of technology through their creative expressions.

3.5. Written material

We aimed to gain a deeper understanding of the students' perspectives on the concept of technology and how they expressed it through their iMovie film. We were particularly interested in uncovering the aspects they thought were significant to highlight and their creative choices in presenting their ideas. By exploring the students' reflections, we sought to find the underlying thoughts and motivations that guided their filmmaking process, going beyond what may be immediately apparent in the film itself.

4. RESULTS

This section provides an overview of the studied movies, accompanied by selected frames that capture key visual expressions. To give you an overview of the analysis and visuals of the movies we have supplied Table 1 as help. Following each movie description, we will present our analysis based on the findings.

Table 1:
Students' movies

Movie	What we saw	What the students described	Nouns and adjectives used in the reflective texts
Film nr 1 – The Globe 	The difference in water availability and living standards around the world	The film shows how technology is used differently worldwide, seen from a global perspective.	Injustice, rest, laziness, Earth, human, furniture, faucet, electric stove, refrigerator, freezer, mobile phone, weapon, drone, bomb, water, mug, child, city, lighting, cars, White goods, television, pots, carrying shawl, pure (water), poor,
Film nr 2 – Love Is In The Rain 	The evolution of rain protection, from a leaf to an umbrella	The film aims to show the good side of technology's Janus face.	Bus stop, trees, birds, stone, road, buildings, cars, parking lot, clay figures, umbrella, clouds, raindrops, hearts, angry, sour, jealous, dry, wet, joy, laughter, love
Film nr 3 – Abdi's apartment 	The human social impact of technology (the mobile phone)	The use of technology facilitates everyday life, but when the use becomes a burden instead of an asset.	Apartment, living room, kitchen, sofa, TV, kitchen counter, window, friend, package, telephone, mobile phone, the light, feeling, anxiety, change, recognise, scroll, obsessed, Available, Like, Energy, Social, Fun, Dirty, Flipped

4.1. Technology from a Bourdieusian perspective

We here summarise the states as we initially observed them in our data. The states are Objectified (O), Institutionalised (I) and Embodied (E).

Movie 1

- O: Different water technologies used or designed

- I: Not everyone has access to water and water of good quality. Only the rich part of the world has
- E: Again, the rich part of the world can tell who can and cannot use the technology to purify water.

Movie 2

- O: We see artefacts in the movie that speak to us that is technology that not only the single individual can take part in the bus stop, trees, birds, road, buildings, cars, parking lot, umbrella
- I: Not everyone has protection against rain. Not everyone has an umbrella when it is most wanted to shelter the rain.
- E: Having a rain cover daily is an access of luxury.

Movie 3

- O: We see artefacts in the movie that speak to us - technology in an apartment: living room, kitchen, sofa, TV, kitchen counter, window, friend, package, telephone, mobile phone,
- I: The mobile telephone is, perhaps today, a technological artefact that almost everyone can use. However, not everyone can have it as a pastime. Furthermore, when it becomes a pastime, it can become something you can be addicted to.
- E: We cannot allow or restrict the use. The technological industry has no limits and sets its rules to a large extent.

4.2. Adding the students' reflections

In the text, the students reflected on the film they created. They showed an awareness of how they perceive themselves and their environment from a broader, global perspective.

Excerpts drawn from the reflections of Film #1:

> The film is important because it shows injustice and differences in society. For me personally, the film evokes a lot of emotions and thoughts about how unfair we have it.
>
> It is scary and sad that technology developed to help does not reach everyone who needs it and how technology is used to destroy.

Excerpts drawn from the reflections of Film #2:

> The film's purpose is also to show that we humans can be brought together and create new relationships with the help of technology. In the film we can draw parallels to our

> private life, with examples of waiting for the bus, meeting someone, romance, attractions, and caring.

Excerpts drawn from the reflections of Film #3:

> The film was like food for thought for me. There are so much fun and other things to spend time on than surfing away a whole day. I realised the negative aspects of the phone, and the Janus face of technology became more apparent.

The excerpts were chosen as they pointed to different perspectives described by the students. Film #1 gives an example of their sociotechnical understanding as students themselves highlighted the societal perspective. Film #2 excerpt shows how artefacts influence human activity and life. Film #3 put forth the student's relationship with technology.

5. ANALYSIS

The movies were watched multiple times during data management sessions. Initially, the authors watched the movies together in silence while taking notes. Subsequently, we engaged in content discussions, drawing upon our diverse subject backgrounds. Finally, we sorted the movie content based on our specific subject knowledge, allowing for an analysis of the movies' themes and messages compared to the written material we collected.

5.1. Analysing the data

In analysing the data, which consists of three movies and nine pages of by students' written material, we first employed an inductive analysis approach to sort the data from a STEAM perspective. In our study, the STEAM perspective means an interdisciplinary approach but with the foundations of each subject's content knowledge. For the S in STEAM, this meant focusing on all aspects of the natural world. The T, E and M were highlighted as all things made by humans, solving a problem, or designed to solve one. Here, the technological knowledges as described by Nordlöf et al. (2022) was used. The A approached the data by looking at the different aspects of the aesthetic process and language.

Based on nouns and adjectives from the written material, this first step gave us four categories – traits, emotions, artefacts, and environment. The categories came from its connections to STEAM. Art here represents words describing human beings as social creatures, Technology, Engineering, and Mathematics represent words describing the human-made world, and Science represent words describing the natural world.

These categories served as guides into the Bourdieusian perspective and what we, as researchers, saw in the movies. We then could match the three states, Objectified (O), Institutionalised (I) and Embodied (E), with the four categories. We present the categories and examples of nouns and adjectives matched.

Category one, traits combined with Bourdieusian perspectives: laziness, jealousy and social. We analysed this category as being both institutionalised and embodied due to its possibilities for actors or groups having access to and specific ways of using technological artefacts. It possesses the ability to permit or restrict the use of technological artefacts in particular ways.

Category two, emotions, combined with Bourdieusian perspectives: injustice, anger, and anxiety. We analysed this category being institutionalised as they pointed to how usage and access impact being human.

Category three, artefacts, combined with a Bourdieusian perspective: the freezer, cars, and apartment. We analysed this category as being objectified. This is because they encompass all the technologies owned, used, or designed by individuals or groups.

Category four, environment, combined with a Bourdieusian perspective: Earth, raindrops, and light. We analysed this category as an embodiment. The natural world becomes an actor possessing the ability to permit or restrict the use of technological artefacts in particular ways.

6. DISCUSSION

While this study has limitations due to its specific setting and narrow scope, a few conclusions can still be drawn.

Drawing upon Bourdieu's framework (1979), we could unpack the students' perception of technology before engaging in formal technology education teachers' preparation program coursework. The movies displayed examples of technical skills as they presented artefacts in context but not how they worked, just that they did work. Their socio-ethical understanding was dominant as they, in the movies, showed an understanding of how humans are in relation to technology. Nevertheless, there is a dualism in their expression of technological knowledge. There is a difference between the narrative of the movies and the written reflections. The technological perspectives became more visually conveyed in the movies when the students' reflections were communicated to us through a Bourdieuan lens (1979); we observed that the movies represented objectified, embodied, and institutionalised artefacts from a Western and modern perspective of technology, ethical issues and the social understanding of technology.

Regarding the movie "Abdi's Apartment", it surprised us to find the student's film's impact on themselves. They started to question the time they consumed on their smartphones. The students' written reflections raised questions in us about what else we, as teachers, miss when we have little time to reflect with the students. How students perceive and define technology can impact our future teaching and learning.

When the students engaged in creating a stop-motion movie, it allowed them to learn skills such as working with clay, constructing environments, and using movies as a means of communication while exploring technology. The relationship between what the students did and what they understood fostered a learning experience beyond mere unreflective action. The distinction between simply "making a movie" and the learning process that resulted from the students' engagement with animation lies in their awareness of the connection between their creative output and their reflective thinking.

The work and care the students gave in creating the film we analysed as an aesthetical experience that they can use to meditate on a technological perspective. Art becomes a language with which they can communicate and convey a message. The aesthetical approach is more than making a movie. Through filmmaking, the students have the opportunity to create their own world, an essential part of their experience of being human in the world. This differs from technology and Science, where the students are expected to step into an already fixed world. For example, in technology, there are technical rules and standardisation symbols, and in Science, we have agreed on names of species that the students need to learn to be a part of those worlds. In the storyboard, an imaginary world is created based on one's and others' experiences. The aesthetic creation is a central part of this process, and the students can use this newly acquired knowledge in their future profession as a teacher.

Aesthetic learning processes can serve as a tool for understanding students' existing and emerging technological capital but transforming it into a tool for learning requires a different approach. The experience described in this paper highlights the importance of changing one's teaching to allow the students to show their knowledge. In Sultan et al. (2022), the students did not have storyboards, and they did not write reflections. In this study, those pieces made all the difference, making it possible for us to see the students' technological capital.

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Students' Reasoning About Sustainable Development in Relation to Products' Life Cycles

Maria Sundler, KTH Royal Institute of Technology, marisand@kth.se
Ellinor Hultmark, KTH Royal Institute of Technology, ellinorh@kth.se

ABSTRACT

In this study, we investigate Secondary School students' reasoning about products' life cycles in relation to three dimensions of sustainable development: economic, social, and ecological sustainable development. Production and consumption are part of a complex socio-technological system that affect nature and life on earth, and knowledge about this complex system are required to achieve sustainable development. In technology education, students can have the opportunity to reason about products and their life cycles. Hence, this study aims to explore what emerges in students' reasoning about products' life cycles in relation to sustainable development. Data collection was conducted in Sweden through two semi-structured interviews, with students participating in focus groups containing 3 and 4 participants in each group. All student responses have been analysed using thematic analysis to explore dimensions of sustainability. Results show that the students' reason with regard to all three dimensions of sustainable development. However, the three dimensions occur to varying extent within the different phases of a product's life cycle. Additionally, the students also connect dimensions in their reasoning, with both harmonious and contrasting perspectives. Participating students' reasoning indicated traces of an anthropocentric view. These results have implications for technology education, both related to content and practice, which is an important step towards education for sustainable development.

Keywords: Technology education, Sustainable development, Product life cycle, Reasoning

1. INTRODUCTION AND BACKGROUND

The interaction between production and consumption constitutes a complex socio-technological system that impacts the environment and the overall well-being of life on our planet. For production and consumption to be sustainable, consideration should be given to the entire life cycle of products (United Nations, 2015). Hence, products' life cycles are undeniably intertwined with sustainable development. Despite of the varying focus of perspectives in curricula around the world (Jones et al. 2013), this has implications for technology education where the product life cycle is included. Furthermore, sustainable development is considered an important part of technology education (e.g., Elshof, 2009; Pavlova, 2009) where a holistic perspective with a pluralistic view highlighting the connections between economic, ecological, and social dimensions is desirable (Berglund & Gericke, 2016).

Concurrently, education in sustainable development presents a complexity rooted in the systemic structure of sustainability issues. Studies show that it is important to explore these tensions inherent in sustainability issues to enhance learning about the complexity of sustainable development and to develop skills such as systems thinking and critical thinking (Herremans & Reid, 2003; Sterneäng & Lundholm, 2012). In line with this, students' assignments were analysed by Öhman & Öhman's (2012) based on the social, ecological and economic dimensions. The results showed that the students referred to all three dimensions and also interrelated them. However, the study concluded that the students described these relationships as harmonious and did not identify conflicts of interest between the dimensions.

Additionally, there are different moral and philosophical views associated with the concept of sustainable development. With an anthropocentric view, humanity is at the centre, and nature's resources are there for humans to use. An alternative view, ecocentric, places nature at the centre, and humans are a part of the natural ecosystem (Dobson, 1996). Moreover, Pavlova (2009) proposes that weak anthropocentrism, which promotes the mutual thriving of human and non-human nature, is suitable for education in sustainable development within technology education.

1.1. Aim and Research Questions

In technology education, students have the opportunity to engage in reasoning about products and their life cycles. Gaining knowledge about students' reasoning in relation to sustainable development is important for practitioners within technology education, as well as for further research. However, limited research has been conducted regarding this. Hence, our aim is to investigate what students reason about in relation to sustainable development, guided by the following research questions.

1.1.1. Research questions

(iii) What emerges in students' reasoning about the life cycles of products in relation to the social, ecological, and economic dimensions of sustainable development?

(iv) How are these dimensions connected in the students' reasoning?

2. THEORETICAL FRAMEWORK

In this study, Toulmin's Argument Pattern, as described by Erduran et al. (2004), was used as a theoretical framework for students' reasoning. Previously, it has been used as an analysing tool in studies to frame students' individual, as well as collective, reasoning (Erduran et al.). In Toulmin's Argument Pattern, reasoning consists of a *claim* that is supported by relevant *data* and that *warrants* establishing a connection between the data and the claim. To concretize or strengthen the warrants a *backing* can be made. Additionally, the reasoning can consist of *rebuttals* that identify specific circumstances in which the claim would not remain valid.

To theoretically frame sustainable development, the United Nations Commission for Sustainable Development (CSD report, 2001) was used, where sustainable development contains environmental, social and economic dimensions. The framework was developed to form indicators for corporate social responsibility, and it states factors for each dimension. For the social dimension, the themes are equity, health, education, housing, and security. For the environmental dimension the factors are atmosphere, land, oceans, seas and coasts, fresh water, and biodiversity. While for the economic dimension, they are consumption and production patterns and economic structure.

The product life cycle can consist of different phases. In this study, we view this life cycle as consisting of four phases: Production, transportation, usage & maintenance, and disposal. This has been adapted from the phases used by Vaesen (2012) with modifications to be relevant in the context of technology education.

3. METHOD

3.1. Data collection

To obtain a rich dataset of students' descriptions (Robson & McCartan, 2016), data were collected through two semi-structured interviews, where ninth-grade students (15-16 years old) participated in focus groups of 3 and 4 participants at two different schools in Sweden. Focus groups were chosen because students' reasoning can be enhanced when they are stimulated by each other's thoughts and comments (Robson & McCartan). Open questions related to the product life cycle were asked, with follow-up questions when the students' answers needed elaboration. For example, the question used to prompt reasoning about production was: "What do you know about the production of things like clothes and footballs, or mobile phones?". The interviews were audio recorded and subsequently transcribed manually.

3.2. Data analysis

The data was later analysed through thematic analysis, as described by Braun and Clarke (2006). During the analysis process, the authors adopted an interpretive approach regarding what the students were expressing (Braun & Clarke). From the theoretical framework, a code-scheme was established (Table 1). The transcripts were read and reread, and an initial coding of the data was performed separately by both authors using the code scheme. The coding was then discussed, and any uncertainties in the coding were resolved.

Table 1.
The code scheme used in the thematic analyses.

Sustainable development	Product life cycle
Social dimension	Production
Ecological dimension	Transportation
Economical dimension	Usage & Maintenance
	Disposal

Afterward, sections that were deemed relevant to the research questions and where the students were regarded to be reasoning following Toulmin's Argument Pattern, as described in section 2, were selected for further analysis. A second, repeated deductive coding of the relevant sections was conducted jointly by both authors using the code scheme described in Table 1, combined with inductive coding. Themes were then formed connected to each dimension of sustainable development and to each phase of the product life cycle. In a subsequent stage, themes were formed inductively to answer research question (ii). These themes were evaluated, and through discussion between the authors, the themes were refined to have clearer distinctions from each other.

4. RESULTS

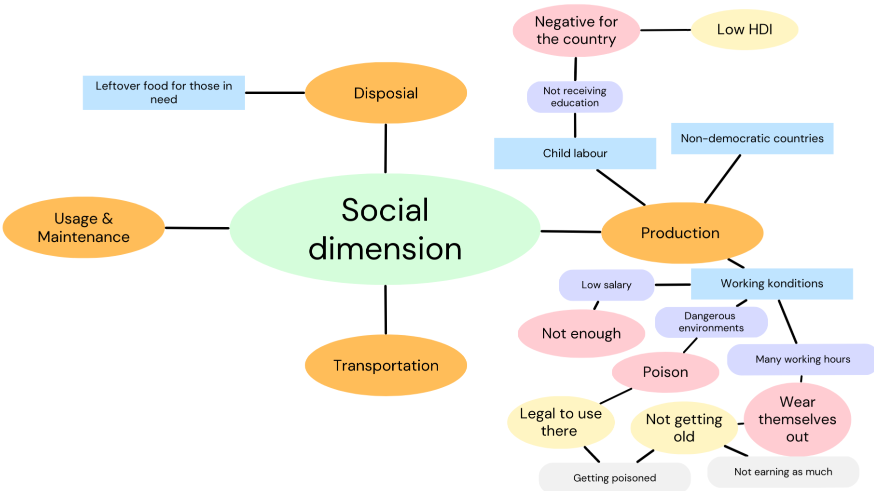
4.1. What emerges in students' reasoning about the life cycles of products in relation to the social, ecological, and economic dimensions of sustainable development?

The participation students mainly reason from the social dimension when considering the production of goods. However, when students reason about transportation and disposal, the ecological dimension becomes notably prominent. The economic dimension is predominantly evident when these students' reason about consumption and transportation.

4.1.1. The Social Dimension

The students' reasoning is primarily centered on the social dimension when they consider the production of goods (see Fig 1). In the production phase, both groups focus on the clothing industry, specifically the cotton industry. They claim that production is situated in other countries like Bangladesh, China, and Vietnam. Both groups' reasoning reveals that this production industry features poor working conditions, child labour, and takes place in countries that, in some cases, are not democracies (see Fig.1).

Figure 1.
Illustration of what emerges in the students' reasoning about products' life cycles in relation to the social dimension



Excerpt A shows students reasoning about working conditions and child labour. Alice reasons that the workers do not manage financially on their salaries, work long hours, and wear themselves out, which affects their health, and in the long run, their life expectancy and total lifetime income. The students' reasoning also reveals that the workers in this production are exposed to poison. Alex claims that these dangerous substances cause poor health and premature death. When the students reason that there is a lot of child labour, they do so in relation to the children's opportunity for education. Jane says that the Human Development Index (HDI) of these countries is low, but it would increase if the children were educated instead of having to work.

Excerpt A

Alice	But it's not only child labour, it's working conditions in general with long hours and low pay. They wear themselves out until ... so they don't get very old, so they don't have the energy left to work when they get older, which means that they can't earn as much money and they can't live on what they earn because the salary is far too low.
Alex	In many cases it is also ... it can be really dangerous environments they work in. Poisons and so on are very often used, and it is permitted in many countries to use life-threatening pesticides and so on, where many people die or are seriously injured.
Jane	But in the cotton industry, this happens every year and many people are poisoned, but another problem with child labour is that it is negative for the

	country in the end because they are not educated, so they can't help move society forward, that's what I was going to say. So what is it called? Their D..i..
Nina	HDI
Jane	Yes, their HDI is low, and it could be raised if the focus was on educating children for just one more year.

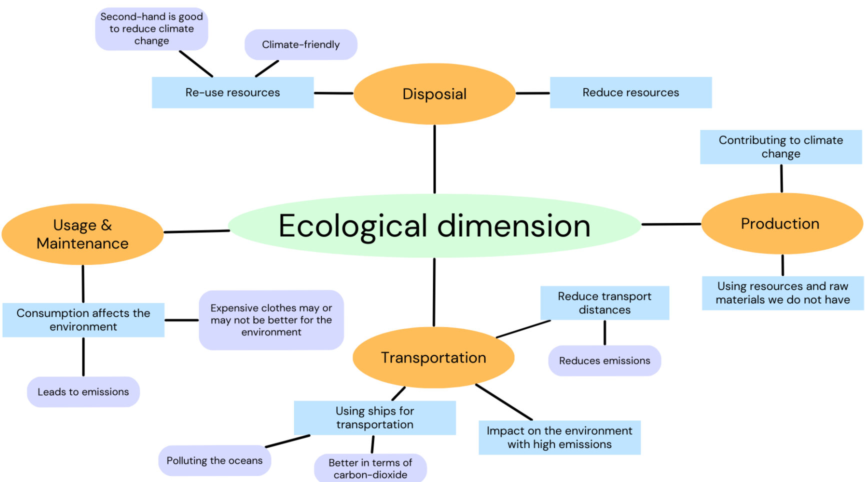
The social dimension is absent in the student groups' reasoning about transportation and usage & maintenance. In their reasoning about disposal, the social dimension briefly appears when they reason that unused food raw materials can be prepared and given to people in need.

4.1.2. The Ecological Dimension

The ecological dimension stands out particularly when the students reason about transportation and disposal. The students reason about what they consider to be a good way of transporting goods based on its environmental impact. The reasoning reveal that transportation affects the environment due to its high emissions, the common use of ships, and the potential emissions reduction if distances could be decreased (see Fig. 2).

Figure 2.

Illustration of what emerges in the students' reasoning about products' life cycles in relation to the ecological dimension



Alice claims that boats are better than airplanes "in terms of carbon dioxide". However, in the same sentence, Alice also mentions that using boats is negative due to sea pollution. Likewise, Jane argues that transport distances are "unnecessary", and if these could be reduced, emissions would decrease (see Excerpt B).

Excerpt B

Jane	I think many people have also started using boats, which is better, if you think in terms of carbon dioxide. But then it pollutes a lot of our oceans, so that's the negative.

In connection with disposal, several students state that raw materials and resources can be reused, leading to a reduction in our consumption of them. Student Alex also claims that recycling is beneficial for reducing climate change and links it to the substantial production of goods, which currently contributes to climate change. Thus, Alex states, it would be advantageous if we could increase reuse.

The ecological dimension also appears in connection with the consumption of goods, where the students mention the environmental impact of consumption. They also reason about the distinction between online purchases and in-store purchases, both of which are acknowledged to impact the environment and result in emissions. However, Noa suggests that more expensive goods can be better for the environment than cheap ones, whereas David counters that this is not necessarily true; you might just be paying for the label (see Excerpt C).

Excerpt C

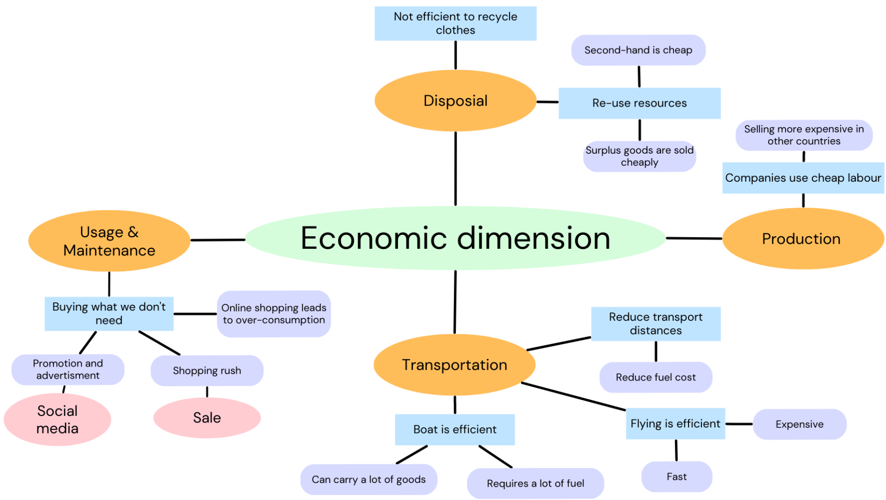
Noa	*Yes, and the goods that are better for the environment are usually more expensive. And then you have to think, should I pay more for the same product and be a little better or should I take cheaper products that are worse for the environment, but then people usually start to think that the environment is not affected, or this choice does not affect - although it might.*
David	*Then ... we can also ... that's .... Yes. The fact that it's more expensive doesn't always mean that it's better for the environment - you can also just pay for the label.*

Among the students, the terms 'carbon footprint', 'climate-smart', and 'helping the environment' are not further defined or explained. The concept of emissions is not exemplified. Nor does their reasoning explain why high fuel consumption and long, unnecessary journeys are considered negative.

4.1.3. The Economic Dimension

The economic dimension is predominately evident in the students’ reasoning about usage & maintenance and transportation (see Fig. 3). They reason that we buy more than we need due to buying frenzies, which are reinforced by recurring sales such as Black Friday, Single Monday, and Cyber Monday. Additionally, they note that there are constant new trends and a lot of marketing (on social media) that unconsciously influences us to buy more.

Figure 3. Illustration of what emerges in the students' reasoning about products' life cycles in relation to the economic dimension



The students emphasise that the buying frenzy leads to mass production, which requires more resources and raw materials than we have and need (see Excerpt D for example).

Excerpt D

Alice	*You are sort of attracted in everything you do, as soon as you walk out the door you see adverts. Your head is always set on buying new things, which means that mass production becomes extreme and then you use resources and raw materials that you may not really have or need.*

Regarding transportation, the students mention that boats and airplanes are the two most common modes of transport. They reason that both boats and airplanes are efficient but possess their own advantages and disadvantages. Flights are fast but come at high cost. Boats, on the other hand, are noted by the students to be time-consuming and fuel-intensive, yet capable of transporting large quantities of goods and being more environmentally friendly "in terms of carbon dioxide". Jane suggests how the transport route could be made more efficient to reduce unnecessary long journeys. She explains that cotton is grown in one place, processed in another place, and then warehouses and shops are located at further distances from each other. She points out that cotton cannot be grown in Sweden, but processing could occur near the cotton farms, with each country having its own warehouse. She reasons that her proposal would reduce transport, which not only results in lower costs and emissions but also saves time.

In the production phase, the students reason that companies use cheap labour to be able to produce cheaply and then sell more expensively in other countries. Alice says that profits can be brought back into the business to increase the productivity and efficiency of the farms, which means that they earn more money for the country. In the end, she claims, the people who work there can also earn more and have better conditions. The economic dimension linked to disposal arose when the conversation shifted to the resale of goods, and the students' reason that surplus food and second-hand items can be sold at lower prices.

4.2. How are these dimensions connected in the students' reasoning?

The results show that when the students reason about products' life cycles they express connections to each dimension of sustainable development. However, they also establish connections between the dimensions, and the inductive analysis resulted in three themes: The Dimensions are Isolated, The Dimensions Harmonise and The Dimensions are Contrasted.

4.2.1. The Dimensions are Isolated

Within the students' reasoning, the dimensions occasionally occur isolated from each other, meaning that the students only reason from one perspective of sustainable development. This is particularly prominent when they reason about the social dimension in relation to production. During such instances, their reasoning is characterized by a lack of rebuttals and connections to the ecological or economic dimensions. In Excerpt E, the students Nina and Alex can be seen reasoning about poison and working conditions.

Excerpt E

Nina	There are also a number of toxins in the production process. and the workers get sick from it and don't get the best care, so it's kind of horrible.
Alex	*In many cases it is also ... well, it can be really dangerous environments they work in. Poisons and so on are very often used and it is permitted in many countries to use life-threatening pesticides and so on, where many die or are seriously injured.*

Within this reasoning (Excerpt E), they emphasise that issues related to workers' health arise when companies use poison in their production. These are aspects related to the social dimension of sustainable development. However, they do not establish connections to, for example, the ecological dimension and how the same poison affects ecosystems. This is characteristic of the students' reasoning, where the social dimension is rarely linked in any way to the ecological dimension.

4.2.2. The Dimensions Harmonise

The students express that the economic and ecological dimensions harmonise when they reason in connection with transportation and disposal. When reasoning about transportation, Jane states that shortening the transportation distances would decrease emissions and simultaneously lower the costs of fuel (see Excerpt F).

Excerpt F

Jane	*These are very unnecessary transport distances, and it would be possible to eliminate many thousands of kilometres and thus reduce emissions, simply by reorganising a little, and everyone would benefit in the long run because there would be lower fuel costs.*

Furthermore, when they reason about disposal, they do so with regard to the same dimensions, economic and ecological. They express that reusing resources, such as buying second-hand or utilising food waste, is both cost-effective and climate friendly.

4.2.3. The Dimensions are Contrasted

The dimensions are primarily contrasted when the students' reason about production and usage & maintenance. The economic and social dimensions are contrasted when they reason about production and companies' economic growth. The students state that companies use inexpensive labour with poor working conditions and child labour to promote economic growth. When reasoning about usage & maintenance, the students contrast the economic dimensions in terms of purchasing cheap or expensive products and relate this to the ecological dimension. They do this by reasoning about making compromises on the ecological dimensions to purchase cheaper products.

5. DISCUSSION

The sustainability dimensions manifest to varying degrees in the students' reasoning about different phases of a product's life cycle. In connection with the social dimension, they predominately reason from the perspective of workers during the production phase. However, the students do not reason about working conditions or child labour in any of the other phases of a product's life cycle. Here, the students reasoned thoroughly, but the same depth is not evident in the other dimensions. For example, in the ecological dimension, terms like "emissions" and "unfriendly to the environment" were not elaborated further. This may indicate that the students have more knowledge about production linked to the social dimension or that they consider this important and want to make visible. Another reason for the reasoning about other dimensions are less specific is that there might be unspoken truths so that the students do not feel the need explain further.

Öhman & Öhman (2012) showed in their study that students seldom reason about conflicts of interest and that the dimensions tend to harmonise with each other. The students in this study also reason about how the dimensions harmonise with each other but also that conflicts of interest can arise between them. This mirrors the relationship between sustainable development and the product life cycle which is full of contradictory objectives. Berglund and Gericke (2016) stress that the connections between the dimensions, whether harmonising or not, should be emphasised in education for sustainable development.

The students in this study reason deeply regarding the social dimension linked to production, yet connections are absent when they reason in relation to the ecological dimension. In both student groups, they reason solely with the focus from the human perspective. For instance, it is mentioned that poison is released during production, impacting human health; however, no connections are drawn to the ecosystems as a whole and how plants and other animals also can be affected by the poison. Hence, traces of an anthropocentric view can be inferred from these students' reasoning. On this matter, Pavlova (2009) asserts that a weak anthropocentrism, where nature and humans mutually thrive, would be a desirable direction for technology education in the pursuit of achieving sustainable development.

These results have implications for technology education, both related to content and practice. Practitioners can utilise the knowledge and insights into how students might reason about sustainable development and product life cycles to plan and develop technology education. Simultaneously, these results serve as a foundation for further research in the pursuit and exploration of technology education for sustainable development.

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Teachers' Perceptions and Impressions of the Forest and the City as a Starting Point for Teaching Biomimicry

Maria Svensson, University of Gothenburg, maria.svensson@ped.gu.se
Alexina Thorén Williams, University of Gothenburg, alexina.thoren.williams@gu.se
Dawn Sanders, University of Gothenburg, dawn.sanders@gu.se

ABSTRACT

The study aims at professional development directed towards finding new pathways in education for and in sustainable development. In this study, we consider the ways in which primary teachers from two schools in Gothenburg, Sweden, experience the forest and the urban environment as potential learning environments. The teachers' descriptions are the basis for introducing biomimicry as a way to strengthen teaching in, and about, sustainable development. Biomimicry has the potential to bridge knowledge of forest ecological systems and how these can be imitated in human-made technological systems in the urban environment. The research questions that this study focuses on are what experiences and understanding of the two places, the urban area, and the forest, are in the foreground of teachers' reflections? In what ways does the collage method make visible teachers' relationships with the urban environment and the forest? The collage method was used to stimulate teachers' reflection, conversation and writing about forest and urban environment. Data were collected when groups of 3-4 teachers in each group, first illustrated their experiences and understandings of the environments individually and secondly described their collage as a written text and in conversation with the group. Emergent findings indicate that the collage method brought out teachers' emotions, perspectives, and curiosity about the forest and the urban environment, which are powerful tools in teaching and engaging students.

Keywords: biology education, technology education, collage inquiry, practice-based research

1. INTRODUCTION

The study presented in this paper is part of a collaborative practice-based research project aiming at finding new paths in education for sustainable development through school subjects, technology, and biology. Biomimicry forms a bridge between knowledge of the ecological systems in the forest and how these systems can be imitated in the human-made technical systems in an urban environment for increased sustainability (Svensson, Sander & Williams 2022). The urbanisation of society indicates that the distance between people living in urban environments and nature is increasing. Teachers' experiences and understanding of how technical systems in the urban environment and ecological systems are structured and function have significance for how they view the world and by extension how questions about sustainability issues can be tackled in the classroom.

Reflection is viewed as one of the powerful ways for teachers to develop their knowledge (Dillon, 2011) and a sense of being able to handle teaching subject content in relation to sustainability issues in the classroom. In this study, we explore an art-based method to stimulate reflection. The method, which is inspired by Butler-Kisber's (2018) chapter in Qualitative inquiry: Thematic, narrative and arts-based perspectives and is called 'Collage inquiry'. The purpose is on the one hand to mapping of teachers' experiences and understanding of nature and urban environments, and on the other, to evaluate the potential of the collage method as a tool for stimulating reflection and making different perspectives visible.

The teachers' experiences and understanding of the forest and the technologically urbanised environment, lay the ground for their bridging of the two environments to address sustainability issues on a system level in the classroom, which is the overall aim of the practice-based research project that this study is part of. In this paper, we make a distinction between experiencing something and understanding something. Experiencing relates to what we can perceive with our senses, while understanding connects to how we think and what we know about something. In relation to our purposes, these research questions are identified:

- What experiences and understanding of the two places, the urban area, and the forest, are in the foreground of teachers' reflections?
- In what ways does the collage method make visible teachers' relationships with the urban environment and the forest?

2. BACKGROUND

Practice-based research is research where educational and pedagogical research of relevance to the school's development is focused on and problematized by researchers and teachers in collaboration (Nilholm, 2020). Persson (2020) highlights the importance of being careful as researchers, in practical research projects to be able to switch between the necessary closeness and familiarity that one needs to have about the practice one is studying, and at the same time to have a scientific and professional distance. It is therefore important to see practical research as a development of knowledge where one presupposes the other.

Students' understanding of technology's importance to and impact on people, society and the environment is emphasised in the Swedish National Curriculum (Skolverket, 2022). According to this curriculum, technology education should develop the students' technological awareness and ability to relate technological solutions and their use of technology to issues related to sustainable development. By making technological solutions visible and comprehensible in teaching, students are given the conditions to orient themselves and act in a technology-intensive world. In recent years, several researchers (Ingerman & Collier-Reed, 2011; Svensson, 2011) have referred to this type of knowledge or generic skills as *technological literacy*. Technology is about developing and designing new artefacts and systems to change and improve our surroundings. There is a downside to the human drive to constantly develop and change artefacts and systems if consideration is not given to the global and environmental impact a technological world, and to learn to discern the benefits and disadvantages of technology. Therefore, it is of great importance to include sustainability perspectives in design work to find new sustainable ways to develop technical solutions (Pavlova, 2013). Biomimicry is an interdisciplinary discipline that examines how we humans can imitate nature's solutions to develop a sustainable design of, for example, artefacts/objects, processes, or technical systems (Benyus, 1997; Lenau, Orrù & Linkola, 2018). Imitating nature is a common design approach used by industrial companies and design education (Coccia, 2017; Han et al., 2019; Shanta & Wells, 2020). However, in primary schools, biomimicry is a relatively new approach to strengthen teaching in, and about, sustainable development. By combining technology and biology subjects, a bridge between knowledge of technological systems in urban environments and ecological systems in the forests enables new pathways for sustainability education. of this development. According to McCormick (2006) and Keirl (2006) technology literacy is also about enabling students to reflect on their technological lives, to develop critical awareness about how to live in

2.1. Why map teachers' experiences and understanding of the forest and the urban area?

The purpose of gaining more knowledge of the teachers' and our own experiences and understanding of the small forest and the urban areas, is to learn about how we relate to these places personally and professionally in different ways. In doing so, we aim to deepen the capacity to teach beyond the classroom and reflect upon such teaching. The knowledge we gain (as a collective in the project) forms a foundation for the project, which we can build on in the further work of the project.

The small forests near the schools are places where primary school teachers regularly go with their students to play and learn about animals and plants. The nearby urban environments are, in contrast to the forest, areas which are not related to in the same way (Szczepanski, 2013). Urban environments are human-constructed worlds with various artefacts and technological systems that have the purpose of meeting human needs. In this project, both the urban environment and the forest are essential places, for building, through biomimicry, the bridge between technology and biology teaching, where the forest ecosystem(s) with its organisms can inspire and challenge teachers' and their students' thinking about how to design sustainable technical systems.

3. METHOD

The collage method is inspired by Butler-Kisber's (2018) "Collage Inquiry", which can be viewed as an art-based research method. Collage inquiry sets out a specific 'angle of arrival' (Allsop & Dillon, 2018) to engage the participants to reflect upon the forest and the urban areas. Making the collage involves selection, wanting to choose a specific kind of representation and the option to add words and symbols. In creating the collages, the teachers' relations to these places emerge (Butler-Kisber, 2018). In addition to mapping teachers' experiences and understanding of the forest and urbanised environments, making a collage can afford affective elements such as emotions and attitudes. With the collage method, fragments from materials such as magazines, and coloured paper of various kinds of yarn and fabric were used to visualise experiences and understanding of forests and urban environments. The cut-outs that we take from magazines and other materials and put together in a collage provide a tool that allows for expressing and communicating phenomena in a more diversified way. The collage method works here as a tool to stimulate reflection and broaden perspectives and conversations about the forest and the urban environment. The collages constitute visual documents within the practice-based research project of which this study is a part (Butler-Kisber, 2018).

3.1. Participants

The two schools participating in this study reached out to researchers at the teacher education to collaborate around teachers' professional development concerning sustainability. This interest initiated a practice-based research project. Eight teachers from the two primary schools in Gothenburg, and three researchers participated in the collage inquiry workshops. Four of the teachers were teaching students of ages 7-9 and the other four, students of ages 10-12. Both primary schools (students of ages 6-12) were diverse schools with teachers and students with Swedish as an additional language.

The data consists of the collection of photos of the teachers' collages, teachers' descriptions of collages, teachers' interpretations of each other's collages on post-it notes and transcriptions of video- and audio recordings of the collage workshops. The transcribed data is from the part of the workshop when all the collages have been completed and after everyone in the group has taken part in the others' collages and with a few words or sentences (on three separate post-it notes for each collage apart from their own) wrote down his interpretation of the collage.

3.2. The approach to the collage inquiry workshop

The group of teachers were divided into two workshops, 3 teachers in the first one and 4 teachers in the second workshop. We as researchers participated in both workshops. Each workshop occasion took about two and a half hours. Before we started making collages, the researchers prompted these questions: *What are your experiences of the city and the forest? What are your understandings of the forest and the urban environment?* In addition, everyone was instructed to use the materials (magazines, paper, fabric, and yarn) that were presented to make a collage that represents one's perceptions and experiences of these environments.

The work with the collage took about 45 min up to an hour for everyone. Then about 20 minutes were devoted to writing a paragraph about one's collage and giving it a title. After a 15-minute break for refreshments, we all looked at each other's work and, on each collage, everyone had to write down their short interpretations of the collages on three separate post-it notes for each collage apart from one's own. These interpretations could be sentences or words. The Post-it notes were then attached to the back of the collages.

After this step, we all gathered around a large table to present the collages to each other. The presentation followed a given order, where everyone in turn read out the title of their collage and then their descriptive paragraph. Not everyone had time to write a paragraph during the workshop but submitted one later. The participant who presented his or her collage then had to turn the collage with the back facing up and read aloud what was written on the post-it notes attached. An important part of this step was affording the collage owner to comment and reflect on the other participants' interpretations and perspectives. After everyone presented their collages, a discussion followed about the different interpretations and perspectives of forests and urban environments.

3.3. Analysis

The transcriptions of video and audio recordings were analysed through thematic analysis (Braun & Clarke, 2006). Pictures of the collage together with the teachers' written descriptions and the transcribed presentations were read and reread by all three researchers to find themes that describe what experiences and understanding of the two places, the urban area, and the forest, are in the foreground of teachers' reflections in all three sources. The emerging themes were evaluated and through discussion between the authors to describe the special nature of the themes. The analysis is a work in progress and may develop with additional themes.

4. EMERGENT FINDINGS

The collage method makes visible not only teachers' experiences and understanding but their professional identity and personal/private identity in relation to the urban environment and the forest. The collage method brought out emotions, perspectives, and curiosity, which are powerful tools in teaching and engaging students. Three themes, *temporarily situated, place dependent and emotionally connected/attached* emerged in the analysis which describes the character of the teachers' reflections that came into their foreground about their experiences of the forest and the urban environment and their understanding of these places.

4.1. Temporarily situated

In this theme, the teachers are reflecting on the places by looking into the future and/or looking back on history, focusing on humans living close to nature and then moving into cities, becoming more separated from nature. The problems that we see in the urban environment today need to be solved sustainably in the future. New technological solutions will help us in the urban environment, indicating technology positivism. John presents his collage and points at the picture of a child.

Figure 3.
John's collage.

> It is a child who symbolizes the future and who looks up with the hope that it will be even better and more sustainable in the future... at the same time there is a man in fur who reminds us of the old days when the cities were dirty and smelled bad because they lacked knowledge about sustainable living, hygiene and how to build, choose materials and plan....all people and residents have their primary needs, instincts, but all problems need to be solved... in the cities.

Veronica reads her paragraph describing her experiences and understandings of the two environments:

> Once upon a time people thought it was great fun to live in cities and this is [points to an image in the collage] this is the image from the nomads' what is it called, tents that they left in a pile and then they move to the city and very quickly you discover that you need - we have always had the forest at home. An example is the Christmas tree then, which we go to the forest to get when we celebrate Christmas and so on and so forth.

4.2. Place dependent

The teachers describe their relations to the forest and the urban environment by highlighting things to see and do. There are also traces of limitations of the places. In the forest, you can play as a child but in the urban environment, you are not allowed to move around as you want to. The two places invite to and afford certain activities and can thus be seen as complementary and integrated.

Figure 2.
Anna's collage.

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> Anna: When I think of the city, I think of people. Lots of people gathered in one place. Everyone needs somewhere to live, employment, to get to different places by car, bus, tram, etc.[...] In the forest, there is calm, peace, nature, the soothing scents, the moisture after the rain, the sun shining through the trees, a cup of hot chocolate. Good clothes and shoes. Child playing, climbing, running, exploring. Mushrooms, berries, ghost walk, animals, insects. Light, darkness.
>
> Cecilia: My experience of the forest is the silence and at the same time the life of the forest. I also often experience the forest/nature within the city, such as in gardens, farms, forest groves in the city. It shows humans' need and desire to be close to nature, even in the middle of the city [...] my understanding of the city is that it should be accessible, efficient, convenient for people who live there. Water, heating, communication, payment system, sewage, infrastructure (bridges, roads) everything must work. My experience of the city is instead about religion, culture, art, education, and other values found in the city. (The kind that I don't get access to in the forest).

4.3. Emotionally connected

The theme describes teachers' emotional connections to the forest and the urban environment. Their feelings about the urban environment have a more negative character, i.e., stress, high noise level, and disorder, but there are also traces of friendship and belonging. The forest, on the other hand, brings out emotions such as calm, silence and order, light but here too there are negative feelings such as darkness, fear, and uncertainty.

Eva: I listen to the forest outwardly, both for sounds that fill me with well-being but also for sounds that can warn me of danger. In the forest there is peace and quiet but also anxiety. Some of my biggest fears live in the woods – spiders, moose, and wild boar. In the city, I listen inwardly, do what I want to do, spend time with friends and family, go to the gym and exercise [...] But there is also anxiety in the city, anxiety about having an accident - maybe getting hit by a car -, anxiety about running into people who want you badly.

Figure 3.
Eva's collage.

5. DISCUSSION

The collage method stimulated reflections and discussions about personal as well as professional relationships with the forest and urban environment. In addition, the making of collages brought out emotions in ways that we did not expect. Coming together as teachers and researchers, reflecting, and sharing ideas through the making of collages, contributed to self-awareness and a sense of community. With the collage method, different interpretations and perspectives were made visible (Butler-Kisber, 2018). A further contribution of the study is the deepened knowledge of the teachers and our own personal and professional relationships with the places - a map that can form the basis for continued work and development of teaching for sustainable development using biomimicry as a bridge between biology and technology.

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Rethinking Measures of Attitude Toward Technology in Technology Education

Sy-Yi Tzeng, Shih Hsin University, syyit@mail.shu.edu.tw
Kuang-Chao Yu, National Taiwan Normal University, kcyu@ntnu.edu.tw

ABSTRACT

Technology curriculums encompass an interdisciplinary approach that integrates science, engineering, the arts, and mathematics, along with a design-oriented learning process. Given the rapid advancement of technology and the challenging environment, technology education has the potential to enhance students' positive outlook on technology. The objectives of this study are to gather existing student attitude scales for technology education, analyse the cognitive, affective, behavioural, and environmental components of these scales, and describe the measurement format and its application. This study referenced established research procedures and instructions, used keywords to research and examine the literature, and collected literature on relevant scales. Afterwards, a coding framework was developed based on the theoretical structure of this study for the research content analysis. Last, descriptive data and critical analysis information were reported. The results of this study can offer a comprehensive component structure for the development of attitude scales in technology education. Furthermore, they will contribute to a more comprehensive understanding of how research in technology education investigates students' attitudes.

Keywords: attitude, perception, attitude toward technology

1. INTRODUCTION

In the early 1980s, Jan Raat and Marc de Vries et al. (1985) conducted an international study on attitudes toward technology called Pupils' Attitude Toward Technology (PATT), which marked the beginning of studies in this field. The PATT study focuses on measuring individuals' cognitive, affective, and behavioural attitudes toward technology, which includes personal interest, role pattern, consequence, difficulty, curriculum, and career categories (Ankiewicz, 2019a). The development of the PATT scale and its study of pupils' attitudes toward technology have widely influenced research on technology education, instruction, and curriculum design, leading curriculum designers to plan technology education programs that meet students' interests and needs. Since then, many scholars have continued to research attitudes towards technology in different countries based on the PATT scale (Ardies et al., 2013; Bame et al., 1993; Becker & Maunsaiyat, 2002; Svenningsson et al., 2021; Van Rensburg et al., 1999; Voke et al., 2003).

In addition to the discussion of the affective component, some studies on PATT have also focused on the cognitive and behavioural components. However, based on Bandura's (1986; 1997) social cognitive theory, studies of learner attitudes also need to explore environmental component effects to be more comprehensive. Therefore, the purpose of this study is twofold: (1) to collect scales on student attitude in the current technology education and analyse the cognitive, affective, behavioural, and environmental components of these scales. (2) to analyse the measurement and application of these attitude scales as a reference for developing a more comprehensive technology attitude scale in the future.

2. THEORETICAL FRAMEWORK

In the model in which technology is manifested, as seen in Mitcham (1994), the formation of technological attitudes mainly results from knowledge, volition, activities (methodology), and objects (ontology) (Fig. 1). Based on Mitcham's (1994:160) philosophical framework of technology, Ankiewicz (2019b) proposed the concept of superposition, meaning that cognition affects emotion and both of them form behaviour (Fig. 2). Essentially, these three attitudes are not independent of each other but rather interact and influence each other. This theoretical perspective has also been widely applied in studies using the PATT scale, which shows how PATT studies have examined students' cognitive, affective, and behavioural attitudes toward technology.

However, Ankiewicz (2019b) highlighted in his research that the mainstream PATT-NL instrument and its derivatives (i.e., PATT-USA and PATT-SQ) have mainly been focusing on the cognitive and/or affective component of attitudes, neglecting the behavioural component. Besides, students' attitudes towards technology are not only dynamically changed by their learning experience but also by the stimulus and influence of environmental factors during the learning process. The social cognitive theory emphasises the interaction of individual, behaviour, and environment (Bandura, 1986; Bandura, 1997). Du et al. (2022) built on Bandura's (2008) model of learner agency to re-emphasise the importance of the environment for problem-based and topic-based team learning (Fig. 3). Therefore, environmental factors should also be a component of PATT research, but it is worth examining whether they have been mentioned in relevant studies.

Figure 47.
Model in which technology is manifested (Mitcham 1994:160)

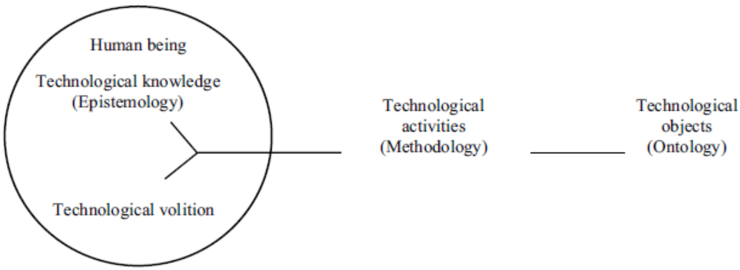


Figure 2.
A superposition of the traditional approach to attitudes and Mitcham's philosophical framework of technology (Ankiewicz, 2019b)

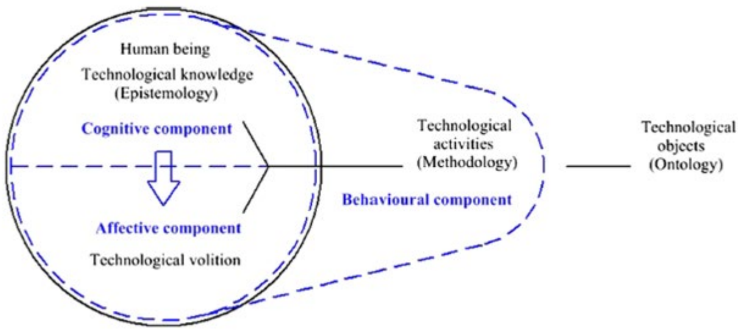
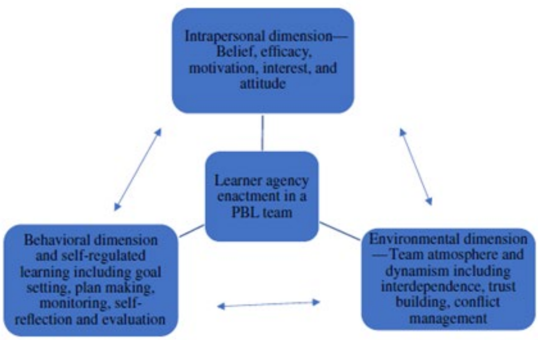


Figure 3.
A model of learner agency in a problem- and project-based learning (PBL) team consisting of three interrelated dimensions (Bandura, 2008)



Based on the above theoretical foundations, this study collected scales on students' attitudes in technology education based on four components: a person's beliefs (the cognitive component), emotional reactions (the affective component), the behavioural component, and the environmental component. On this basis, this study examines how these four components have been explored in PATT measuring scales, and how these technology attitude scales have been assessed and applied.

3. METHODS

To conduct a systematic content analysis, this study follows the research procedures and guidelines (Gao et al., 2020) by conducting literature research and review based on relevant keywords, collecting literature on relevant scales, and developing a coding framework for content analysis based on the theoretical framework of this study (Mitcham, 1994; Bandura, 2008). Finally, descriptive data and key analysis information are reported to provide useful reference results for educational researchers.

The rationale behind the selection of journals underwent a three-stage reflection process. Firstly, a horizontal perspective was considered, taking into account the influence of STEM education trends. It was anticipated that PATT-related research might publish in significant journals within the fields of technology, engineering, and STEM, i.e., International Journal of Technology and Design Education Design (IJTDE), Journal of Engineering Education, and International Journal of STEM Education. Therefore, a search was conducted for article titles and abstracts in these three journals by using keywords (i.e., attitude, belief, efficacy, motivation, interest, and perception). This search obtained 123, 39, and 71 potentially articles over the past decade. Next, content analysis was used on the titles and abstracts of these articles. It was found that PATT-related research was predominantly present in IJTDE, while other journals primarily focused on discussing students' attitudes without adopting PATT measuring scales. Subsequently, a vertical perspective was considered, recognizing that PATT research could also be found in journals within other technology-related journals. Based on the references from IJTDE articles, it was inferred that Technology Education: An International Journal (TEAIJ) and the Journal of Technology Education (JTE) were important journals for the publication of PATT-related research. Therefore, IJTDE, TEAIJ, and JTE were chosen as the journals for systematic content analysis. This outlined process contributes to the validity and reliability of the rationale for this article.

Due to the initial keyword searches mentioned in previous paragraph resulted in overlapping articles. In the final selection of journals, we focused solely on the keywords "attitude" and "perception." The following procedure has been used to conduct this study. First, this study searched for articles with the keywords “attitude” and “perception” from the IJTDE, TEAIJ, and JTE, from which 82, 20, and 7 articles were obtained, respectively, adding up to a total of 108 relevant articles.

Next, the articles were screened by the type of target population, the type of technology attitude, and the type of technology curriculum. The analysis was done by discussion among the authors on the article selection criteria. One of the authors searched the articles in the journal database and used an Excel sheet to organise the results, including: the article title, abstract, and DOI, and then preliminarily categorised the articles by types of research subjects (i.e., student and teacher), types of technological attitudes (i.e., technology attitude, engineering attitude, and STEM attitude), and types of curriculums (i.e., is it a technological curriculum). The outcome was then checked by another author before the final articles were selected for analysis. The research subjects of technology curriculum studies may include both students and teachers; this study, nevertheless, focuses on K-12 students as the target population and only discusses studies on technology curricula and attitudes towards technology, excluding those on engineering attitudes and STEM attitudes. Therefore, three specific criteria were applied. Articles were included if they addressed (a) students as the sample population, (b) K-12 educational settings, and (c) technology curricula. Notably, articles focusing on "attitude" were only considered if they utilized a "PATT measuring scales" for assessment, rather than merely discussing students' attitudes. Finally, a total of 23 articles were selected for data analysis (Appendix A).

Finally, two authors conducted a content analysis together, including: the year of publication, components of technological attitudes, formats of measurement, and comparative analysis of applications. In the coding process, three codes have been configured, with the first code being for the journal, and the second and third codes for the article label. The code number for IJTDE is 1 and there are 17 articles, leading to a code representation of 101-117. The code number for TEAIJ is 2 and there are 2 articles, and therefore the representation is 201-202. JTE is referred to by the code number 3 and there are 4 articles, resulting in 301-304.

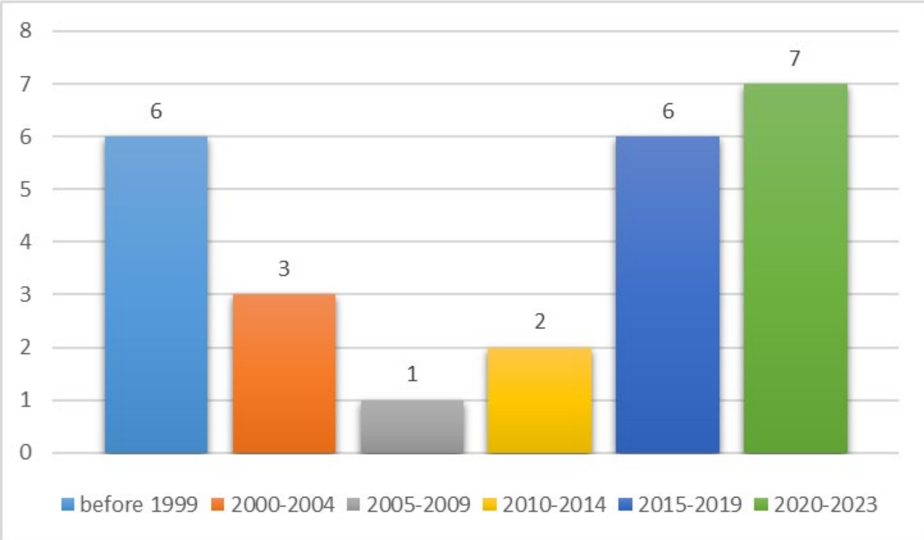
4. RESULTS

4.1. Year of publication

This study's analysis is divided into four sections: First, the distribution of the year of publication of the articles on attitudes towards technology. Second, the components of the articles on attitudes towards technology. Third, the format of measurement in the articles on attitudes towards technology. Fourth, the application of technology attitude scales.

In terms of the distribution of the year of publication of the articles on attitudes towards technology, there were six articles before 1999, three articles from 2000 to 2004, one article from 2005 to 2009, two from 2010 to 2014, six from 2015 to 2019, and seven from 2020 to 2023 (Fig. 4). There is a clear trend of increase in articles on technological attitudes after 2015, mainly concentrated in IJTDE, with 10 articles in all (coded as 108-117 respectively).

Figure 4.
Distribution of articles on attitudes towards technology by year of publication



4.2. Components of technology attitude scales

This study integrates Mitcham's (1994) philosophical framework of technology and Bandura's (2008) model of learner agency theory to classify the components of technology attitude articles into cognitive, affective, behavioural, and environmental types for analysis purposes (Table 1). There are nine articles for the cognitive type, 23 articles for the affective type, eight articles for the behavioural type, and four articles for the environmental type. On the whole, the articles are still mainly concentrated on the study of the affective type, and a few studies have focused on an ongoing basis on cognitive and behavioural discussions, but there is a lack of attention to the environmental type. In articles exploring environmental issues, only climate in the home is discussed. Therefore, it is clear that the development of this part of the scale can be further strengthened.

Table 26.
Components of articles on attitudes towards technology

Components	Articles	Total
Cognitive	101, 103, 106, 112, 113, 201, 301, 302, 303	9
Affective	101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 201, 202, 301, 302, 303, 304	23
Behavioural	101, 103, 105, 108, 109, 112, 116, 304	8
Environmental	105, 301, 302, 303	4

4.3. Format of measurement of technology attitude scales

The format of the measurement of technology attitude scales (Table 2) comprises questionnaires and interviews. All 23 articles analysed used questionnaires and tended to use the Likert scale. Most of the articles used the 5-point Likert scale, while a few used the 4-point Likert scale and the 6-point Likert scale (e.g., 201 and 112). Only two of the analysed articles also used interviews as a means of explanation to supplement the quantitative data of the questionnaires; and both used structured individual interviews (i.e., 103, 110).

Table 2.
Format of measurement of technology attitude articles

Main formats	Articles	Total
Questionnaire	101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 201, 202, 301, 302, 303, 304	23
Interviews	103, 110	2

4.4. Application of technology attitude scales

The application of technology attitude scales can be divided into two types: a survey on the current status of students' attitudes towards technology curriculum and a survey on the change in students' attitudes towards technology when participating in technology curriculum (Table 3). There are 19 articles in the former and four articles in the latter. It can be seen from the data that most of the studies still focus on investigating the current status of students' attitudes towards technology, while a few studies try to examine changes in attitudes. For example, some compare the change in students' attitudes towards technology before and after taking technology curriculum (i.e., 111, 114, 115, 301).

Table 3.
Application of attitude towards technology scales

Means of application	Times of application	Articles	Total
Survey on students' attitude towards technology in technology curriculum	Once	101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 112, 113, 116, 117, 201, 202, 302, 303, 304	19
Survey on changes in students' attitude towards technology before and after participating in technology curriculum	Twice (and more)	111, 114, 115, 301	4

5. DISCUSSION AND SUGGESTION

In planning the attitude scale for technology education, it can be observed that the relevant research has been mainly focused on discussing the affective component, and more exploration is needed regarding the cognitive, behavioural, and environmental components. This aligns with Ankiewicz's (2019b) assertion regarding the neglect of the behavioural component. Furthermore, our study has also revealed a relative scarcity of research focusing on the cognitive and environmental components. Therefore, it is suggested that future PATT research should provide a broader category structure that enables a more complete understanding of the cognitive, behavioural, and environmental aspects of students' attitudes toward technology in technology education curriculum.

In addition, the attitude scales developed in related research studies mainly use the Likert scale of questionnaires, which are mostly designed to discuss positive perceptions. A few studies have developed attitude scale tools or qualitative observations based on the design process of technology activities, for example, Doornekamp (1991) provides students with open-ended items for them to respond about their design skills in cases of design problems, and Hendley et al. (1996) and Svenningsson et al. (2018) adopted qualitative interviews to assess and gain a deeper understanding of students' perceptions of participation in the technology curriculum. These studies not only discuss whether students develop positive perceptions of technology during the curriculum but also find that students are prone to negative emotions during the design process or do not understand the learning objectives that affect their attitudes toward technology.

Furthermore, most studies have focused on the current status of students' attitudes toward technology in a single subject or the overall technology curriculum, and only a few studies have examined changes in students' attitudes toward technology before and after technology design (e.g., Boeve-de Pauw et al., 2022; Volk & Yip, 1996). Therefore, it is still difficult to know the real reasons for the rise and fall in students' attitudes due to the lack of research on students' attitudes towards technology and perceptions during the technology design learning process.

From the results of the above data analysis, this study has concluded that there are three difficulties in the application of the current student technology attitude scale. First, technology attitude scales have mostly been used to investigate students' affective attitudes toward technology curriculum but there is a lack of observation on the cognitive and behavioural attitudes toward technology (e.g., educational interests and career intentions), and even less observation on the environmental effects (e.g., teamwork and teacher attention). Second, the assessment approach shows a lack of research on negative perceptions. In these cases, it is easy for educational researchers to assess educational outcomes through only the overall average results of positive student attitudes, but not from students' negative perceptions of technology to improve teaching strategies. Third, technology attitude scales show a lack of awareness to investigate students' attitudes and perceptions in the technological design learning process. Although some studies have repeatedly used the scale for before and after technological design, it is difficult for them to truly observe students' positive or negative feelings in the design of the curriculum and help teachers identify the more difficult or uninteresting stages of the curriculum for improvement.

In summary, few studies have attempted to examine students' attitudes toward technology from the perspective of the design process, that is, attitudes towards technology as an environmentally influenced and dynamic form of inquiry. From the perspective of career development theories, it is often the feelings and learning experiences that students have during their participation in technology curriculum for K-12 education that shapes their perceptions of self-identity, interdisciplinary education, and career intentions (Hammack et al., 2015; Mohd Shahali et al., 2017).

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7. APPENDIX A:

7.1. List of reviewed articles

Coding Label	Articles
101	Doornekamp, B.G. Gender differences in the acquisition of technical knowledge, skills and attitudes in Dutch primary education: the need for technology education. *Int J Technol Des Educ* 2, 37–47 (1991). https://doi.org/10.1007/BF00275230
102	Householder, D.L., Bolin, B. Technology: Its influence in the secondary school upon achievement in academic subjects and upon students' attitude toward technology. *Int J Technol Des Educ* 3, 5–18 (1993). https://doi.org/10.1007/BF00454392
103	Hendley, D., Stables, A., Parkinson, J. *et al.* Pupils' attitudes to technology in key stage 3 of the national curriculum: A study of pupils in South Wales. *Int J Technol Des Educ* 6, 15–29 (1996). https://doi.org/10.1007/BF00571070
104	van Rensburg, S., Ankiewicz, P. & Myburgh, C. Assessing South Africa Learners' Attitudes Towards Technology by Using the PATT (Pupils' Attitudes Towards Technology) Questionnaire. *International Journal of Technology and Design Education* 9, 137–151 (1999). https://doi.org/10.1023/A:1008848031430
105	Volk, K.S., Yip, W.M. Gender and Technology in Hong Kong: A Study of Pupils' Attitudes Toward Technology. *International Journal of Technology and Design Education* 9, 57–71 (1999). https://doi.org/10.1023/A:1008894006039
106	Ankiewicz, P., van Rensburg, S. & Myburgh, C. Assessing the Attitudinal Technology Profile of South African Learners: A Pilot Study. International Journal of Technology and Design Education 11, 93–109 (2001). https://doi.org/10.1023/A:1011210013642
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108	Ardies, J., De Maeyer, S., Gijbels, D. *et al.* Students attitudes towards technology. *Int J Technol Des Educ* 25, 43–65 (2015). https://doi.org/10.1007/s10798-014-9268-x
109	Metsärinne, M., Kallio, M. How are students' attitudes related to learning outcomes?. Int J Technol Des Educ 26, 353–371 (2016). https://doi.org/10.1007/s10798-015-9317-0
110	Svenningsson, J., Hultén, M. & Hallström, J. Understanding attitude measurement: exploring meaning and use of the PATT short questionnaire. *Int J Technol Des Educ* 28, 67–83 (2018). https://doi.org/10.1007/s10798-016-9392-x
111	Boeve-de Pauw, J., Ardies, J., Hens, K. *et al.* Short and long term impact of a high-tech STEM intervention on pupils' attitudes towards technology. *Int J Technol Des Educ* 32, 825–843 (2022). https://doi.org/10.1007/s10798-020-09627-5
112	Xu, M., Williams, J.P. & Gu, J. An initial development and validation of a Chinese technology teachers' attitudes towards technology (TTATT) scale. *Int J Technol Des Educ* 30, 937–950 (2020). https://doi.org/10.1007/s10798-019-09551-3
113	Candela, P.P., Gumbo, M.T. & Mapotse, T.A. Adaptation of the Attitude Behavioural Scale section of a PATT instrument for the Omani context. *Int J Technol Des Educ* 32, 1605–1627 (2022). https://doi.org/10.1007/s10798-021-09665-7
114	Miranda, C., Goñi, J., Pickenpack, A. *et al.* The ethical implications of collecting data in educational settings: discussion on the technology and engineering attitude scale (TEAS) and its psychometric validation for assessing a pre-engineering design program. *Int J Technol Des Educ* 32, 1495–1513 (2022). https://doi.org/10.1007/s10798-021-09653-x
115	del Olmo-Muñoz, J., Cózar-Gutiérrez, R. & González-Calero, J.A. Promoting second graders' attitudes towards technology through computational thinking instruction. Int J Technol Des Educ 32, 2019–2037 (2022). https://doi.org/10.1007/s10798-021-09679-1

116	Svenningsson, J., Höst, G., Hultén, M. *et al.* Students' attitudes toward technology: exploring the relationship among affective, cognitive and behavioral components of the attitude construct. *Int J Technol Des Educ* 32, 1531–1551 (2022). https://doi.org/10.1007/s10798-021-09657-7
117	Purković, D., Kovačević, S. & Luttenberger, L.R. Attitudes of Croatian Pupils on the relationship of Environmental Issues and Sustainable Development with Technology and Engineering. *Int J Technol Des Educ* (2022). https://doi.org/10.1007/s10798-022-09779-6
201	CHE-MING, Yau; CHENG-CHENG, Ong. Pupils' views towards design and technology in Singapore. Design and Technology Education: an International Journal, [S.l.], v. 10, n. 3, may 2008. ISSN 1360-1431. Available at: <https://ojs.lboro.ac.uk/DATE/article/view/Journal_10.3_RES3>. Date accessed: 19 may 2023.
202	ARDIES, Jan; DE MAEYER, Sven; GIJBELS, David. Reconstructing the Pupils Attitude Towards Technology-survey. Design and Technology Education: an International Journal, [S.l.], v. 18, n. 1, mar. 2013. ISSN 1360-1431. Available at: <https://ojs.lboro.ac.uk/DATE/article/view/1796>. Date accessed: 04 may 2023.
301	Boser, R. A., & Daugherty, M. K. (1998). Students' attitudes toward technology in selected technology education programs. *Journal of Technology Education, 10*(1), 4-19. https://vtechworks.lib.vt.edu/bitstream/handle/10919/8203/boser.pdf?sequence=1
302	Becker, K. H., & Maunsaiyat, S. (2002). Thai Students' Attitudes and Concepts of Technology. *Journal of Technology education, 13*(2), 6-20. https://files.eric.ed.gov/fulltext/EJ646589.pdf
203	Volk, K. S., Yip, W. M., & Lo, T. K. (2003). Hong Kong pupils' attitudes toward technology: The impact of design and technology programs. *Journal of Technology education, 15*(1), 48-63. https://vtechworks.lib.vt.edu/bitstream/handle/10919/8309/volk.pdf?sequence=1
304	Autio, O. A. (2016). Changes in attitudes toward craft and technology during the last 20 years. Journal of Technology Education. *Journal of Technology education, 28*(1), 53-70. https://helda.helsinki.fi/bitstream/handle/10138/178732/Autio.pdf?sequence=1

Pupils' Reflections on the Use of a Digital Self-assessment Tool to Identify and Measure Development of 21st Century Skills During Maker Activities in Schools

Susanne Walan, Karlstad University, susanne.walan@kau.se
Helen Brink, Karlstad University, helen.brink@kau.se

ABSTRACT

The number of makerspaces is increasing in the world, and the maker movement has started to become integrated into formal education. Maker environments and maker activities are argued as promoting Key Components for Lifelong Learning, e.g. collaboration, problem solving, creativity, life/social skills and communication. These competences are also referred to as 21st century skills. In this paper, we discuss the use of a digital self-assessment tool (DSAT) for pupils' identification of, and reflections on, their development of these skills. The DSAT was created with gamification as the model where the pupils could reach different levels, receive badges and upload photographs. There were 65 pupils aged 13-15 years, participating in the study, working with different maker activities in technology subject classes, while using the DSAT. Examples of maker activities used in this study included designing a liquid-bottle, programming with Micro:bit and programming with Roblox. Data were collected through group interviews after the activities with all participating pupils and thereafter analysed thematically. The pupils found the language in the DSAT difficult considering their age and thought that the tool was time consuming and troublesome to use. However, the pupils argued that it is possible to develop 21st century skills during maker activities in school contexts and that the skills are of importance for the future. This study contributes with important knowledge about the design of digital self-assessment tools and about design of technology education, to support pupils to identify and develop 21st century skills in makerspace activities in compulsory technology education.

Keywords: Maker activities, self-assessment, 21st century skills

1. INTRODUCTION

Makerspaces have started to be an integrated part of school settings (e.g. Vourikari, Ferrari & Punie, 2019). It is argued that makerspace activities can be seen as conducive environments for learning 21st century skills (e.g. Sheffield et al., 2017; Sheridan et al., 2014) e.g. digital competence; competence in science, technology, engineering, and mathematics (STEM); entrepreneurship; analytical thinking; problem-solving; creativity, etcetera (Vourikari et al., 2019). The European Commission (2019) lists skills that are important for education and for future work: creativity, problem-solving, critical thinking, and digital literacy, often referred to as 21st century skills (e.g. Bell, 2010; Davies et al., 2011; Jang, 2016). However, it can be challenging to assess the development of these skills, and there is a lack of tools connected to assessment of, for instance, creativity (e.g. Sawyer, 2003). In this paper, we present a pilot study where the focus is on how a recently developed digital self-assessment tool (DSAT) can be used to identify development of 21st century skills when pupils are engaged in makerspace activities. Focus is on self-assessment of the skills *collaboration*, *creativity*, *problem-solving*, *life/social skills* and on *communication*. We are also interested in how the tool is experienced by the pupils from a design perspective and if the tool supports the development of understanding 21st century skills.

2. AIM AND RESEARCH QUESTIONS

The aim of this pilot study is to investigate if and how a digital self-assessment tool can stimulate understanding and development of 21st century skills in makerspace activities and how the design of the tool can be supportive in this aspect. The following research questions are posed:

- How do pupils respond to the design of the digital self-assessment tool?
- How do pupils respond to the use of a digital self-assessment tool in terms of understanding and identifying development of 21st century skills during makerspace activities in formal educational settings?

3. BACKGROUND

Makerspace activities were first aroused in voluntary non-formal learning environments (e.g. Sheridan et al., 2014) and are characterised as being open-ended, collaborative, and experimental (Godhe et al., 2019; Nemorin & Selwyn, 2017; Sheridan et al., 2014). Several challenges need to be considered when makerspace activities are implemented in formal school settings based on curricular goals, assessment, and organisational priorities (e.g. Godhe et al., 2019; Walan & Gericke, 2023). Teachers need to relate the activities to learning outcomes and curricular goals. However, there is an interest in integrating makerspace activities into schools (e.g. Oliver, 2016), and one reason for this is to fill the gap of educating for the development of 21st century skills (Samuelsson Wardrip & Brahms, 2016).

Previous studies report that pupils develop 21st century skills and learn about technological information and design when working with makerspace related activities, such as 3D printing (e.g. Coşkun & Deniz, 2021; Novak & Wisdom, 2019). The skills used in the DSAT will be described briefly.

Collaboration can be described as an active form of learning with at least two (a group of) individuals, working together to solve a problem, complete a task, or create a product in a physical or virtual environment (Kirschner et al., 2018; Laal & Laal, 2012; Marinez-Moyano, 2006).

Creativity can be understood as a process over time, where novel products are produced (Sawyer, 2003). However, the novelty can arise from new combinations of previously known elements. Creativity can be seen as a method for problem-solving (Amabile, 1996); thus, in order to develop learners' creativity, stimulating environments and materials are needed (Gauntlett et al., 2010).

Problem-solving can be defined as a process where mental representations of a solution to a problem are created (Jonassen & Hung, 2012). If a problem is ill-structured, i.e. where the information required to solve the problem is incomplete, the pupils need to follow different paths and consider various ideas, and at the same time developing creativity and critical thinking (Lai & Viering, 2012).

Life/social skills can be understood as a combination of different skills that are important for navigating through personal and working life. For instance, to be able to take initiatives; have self-direction; to be flexible, adaptable, and productive; act responsibly and finally, have the ability to inspire others.

Communication can include several different aspects, for instance, the interrelation between reading, writing, speaking, and listening (Thompson, 2020). People with good communication skills can express opinions, discuss, reason, speculate, argue, and debate (Lai & Vering, 2012). They can also listen and communicate in different situations, and they are also good at using multimedia when communicating. In addition, they can inspire and create enthusiasm among others (Lai & Vering, 2012).

Makerspace activities can be a challenge in school settings, since the outcomes can differ a great deal (Lin et al., 2020). However, assessment often concerns three different areas: a) content understandings, b) feelings and attitudes, and c) commitment and collaboration (Lin et al., 2020). The content often refers to programming skills, programming concepts, computer logical thinking, creativity, and problem-solving abilities. In these areas, research literature states that formative assessment can support pupils' understandings and help them increase commitment and learning (Hadad et al., 2020; Maltese et al., 2018). In addition, makerspace activities have a potential to create learning opportunities from failure and the formative assessment can stimulate development of pupils' knowledge (Hadad et al., 2020).

4. MAKERSPACE ACTIVITIES AND SWEDISH TECHNOLOGY EDUCATION

In Sweden, the syllabus on technology education is divided into three parts with different core contents, respectively; grades 1–3, grades 4–6, and grades 7–9. However, the aim of the technology subject and the skills the pupils should develop are the same throughout grades 1–9. Teaching should provide pupils with opportunities to develop; the ability to reflect on different choices of technical solutions; their consequences for the individual, society, and the environment; and how technology has changed over time; knowledge of technical solutions and how constituent parts interact to achieve suitability and function; and the ability to carry out technology development and design work. The teachers have a great deal of freedom in organising the learning environments to meet the aim of the subject. In addition, pupils should be prepared in Swedish compulsory schools for an active, creative, and responsible participation in society with a lifelong desire to learn (Swedish National Agency for Education, 2018). Pupils should also be given opportunities to solve problems, turn ideas into action, and to work both individually and in collaboration with others, with and without digital tools for creation and communication. We focus in this study on the core contents for grades 7–9 (pupils aged 13–15), and we interpret the following contents, which are also connected to makerspace activities.

- How do mechanical and digital technology interact?
- Technical solutions that use electronics and how they can be programmed.

- The different phases of technology development work: identification of needs, research, proposals for solutions, design, and testing. How do the phases of the work process interact?
- Own constructions where control and regulation are applied, among other things, with the help of programming.
- How digital tools can be a support in technology development work, for example, to make drawings and simulations?
- Documentation in the form of manual and digital sketches and drawings with explanatory words and concepts, symbols and dimensions, as well as documentation with physical and digital models.

It is important to note that there are no learning outcomes explicitly addressing 21st century skills in the syllabus for the subject technology. In this study, the teachers, together with the pupils, test the use of DSAT in makerspace activities in formal learning contexts, and where the focus is shifted from assessment to self-assessment. Self-assessment is a broad concept, covering feedback from oneself, with the purpose of generating information that promotes learning and performance (Andrade, 2019). The feedback should be formative in nature; otherwise, it is pointless, argues Andrade (2019). We also find in the Swedish National Curriculum for Compulsory School (Swedish National Agency for Education, 2018) that pupils should develop their ability to assess their own results, hence self-assessment.

5. THE TOOL

The DSAT was developed by partners in a European project in an iterative design process. The relevance of the DSAT to maker activities is explained in detail by Ioannou et al. (2020). In this project, our role was to test the DSAT in classes. The DSAT is supposed to be used by pupils aged 12–18 years, with the aim of making them reflect on their development of 21st century skills in makerspace activities. The tool is designed as a game with different levels to reach, and badges to collect. Within the tool, pupils respond to different challenges and answer questions. There are also possibilities to upload photos of activities where the pupils themselves think they are creative, collaborative, communicative, etcetera.

The DSAT includes written definitions of each of the 21st century skills, so pupils can check the definitions if they feel uncertain about the meanings. Graphically, the tool is designed to appeal to the target group. It is possible to use different devices, such as PCs, tablets, or smartphones, since the tool is based on an online platform.

6. METHODOLOGY

To meet the aim of this study and to answer the research questions, 14 qualitative group interviews were conducted with 65 pupils from lower secondary school (pupils aged 13–15 years). The pupils and their parents provided consent to participate. The participants came from two different lower secondary schools, from six different classes, ranging from grade 7 to 9. The six classes worked with different makerspace activities, planned by the respective teachers in discussion with the first author, in accordance with the European project. Both authors visited the classes and informed the pupils about the project, and each teacher informed the pupils about the DSAT and helped them with guidance when they started to use the tool. Examples of makerspace activities they used include: programming in Scratch and Micro:bit, designing different kinds of packages, and design of an online application for smart phones. These activities were held at the respective school. A final activity was held in localities at the university, in collaboration with the local makerspace. In this final activity, programming within Roblox was performed. The activities lasted between 2 to 6 weeks, with one or two sessions per week. After each session, the pupils used the DSAT, aiming to self-assess what kinds of skills they had been able to develop.

After the final activity, group interviews were held at the university. The groups comprised 5–6 pupils. The interviews were thematically analysed (Braun & Clark, 2006). The second author did the first tentative analysis; thereafter, both authors discussed and compared the themes until a consensus was reached.

7. RESULTS

The analysis resulted in two main themes: *The use of the DSAT* and *The 21st century skills* with sub-themes, respectively (Table 1). The results will be presented next with excerpts from the interviews, named G1 for group 1, G2 for group 2, and so forth (in total 14 groups).

Table 27.
Themes and sub-themes

Theme	Sub-theme
The use of the DSAT	Purpose of using the tool Functional issues with the tool Suggestions for improvements of the tool
The 21st century skills	Understanding Development of 21st century skills

7.1. The use of the DSAT

The first theme includes three sub-themes (see Table 1). The pupils found the *Purpose of using the tool* to be: to evaluate and reflect upon their work or the results of their work. 'I think in retrospect, to be able to check later what we have done, to learn from it, maybe' (G3). There were also statements from pupils not grasping the purpose of the tool. 'I don't understand why you should use it' (G3).

During the interviews, pupils described some *Functional issues with the tool*. Specifically, they stated that the language in the tool was too difficult, there were too many similar questions and loops, and it was time consuming with the need to do many clicks. The pupils did not perceive the tool to be intuitive. In addition, the pupils expressed it was difficult to upload pictures. 'It was complicated words… if you don't read 24/7… it was difficult to understand' (G12).

The pupils described some *Suggestions for improvements of the tool*, albeit this was not asked for during the interviews. They said it would be helpful if the tool had video-instructions for how to navigate and use the tool. 'They could have made a video before, so it was possible to see how to use the tool' (G11). Another suggestion was that the tool could include some exercises for training skills that were not so developed. Finally, the pupils suggested that the questions could be more open-ended to stimulate their reflections about the skills.

7.2. The 21st century skills

The second theme includes two sub-themes (see Table 1). The pupils expressed that the DSAT helped them in their *Understandings* of some of the 21st century skills. 'It makes you reflect. For instance, about how you collaborate with others… so you can improve… if you notice that you never collaborate, you can start doing that' (G14). However, pupils had some difficulties understanding the life/social skills, and other skills seemed to overlap in definitions when the pupils talked about them. One pupil said 'You collaborate automatically and improve communication automatically when you collaborate' (G9).

It was also found that pupils thought about problem-solving in different ways, often linked to everyday perspectives and learning, such as how to open a door. 'Well, a problem can be that when you are a small kid, you cannot open doors, but when you become older, you solve the problem and understand how to do it' (G10).

Further, the pupils believed that it is possible to *Develop 21st century skills* while doing makerspace activities. Above all, the pupils mentioned the skill of creativity and that open-ended activities promote creativity. However, they also said that it is possible to develop these skills by doing other activities as well and that the skills are important for them in the future.

8. DISCUSSION AND CONCLUSIONS

From the results, we can conclude that not all pupils have understood the purpose of using the DSAT. One explanation for this is that the tool may not be intuitive enough for the pupils to understand or that they did not understand their teachers when the tool was being introduced. We are also uncertain about if and how often the pupils have been doing self-assessment activities, which can impact the understandings.

We draw the conclusion that designing a self-assessment tool is a difficult task. Furthermore, the interviewed pupils gave a lot of examples of this, such as requiring a lot of clicks, and too many similar questions in the different parts of the DSAT. Moreover, uploading pictures was considered problematic, both technically and to capture a skill in a photo. The pupils did not know what to focus on in the picture. The language in the DSAT may be too complicated, and the translation from English to Swedish can be improved.

We argue that the role of the teacher is important for helping pupils understand the skills and how to use the tool; having only written definitions in the tool is not enough according to our results. Some pupils suggested videos as complements for support and information.

One finding from this study is that pupils became aware of the 21st century skill when using the DSAT and when participating in makerspace activities, a result also found in other studies (e.g. Sheffield et al., 2017; Sheridan et al., 2014; Vuorikari et al., 2019). During the interviews, these skills were described as being important for the future.

The results also show that some of the 21st century skills are understood as overlapping, for instance, collaboration and communication. Furthermore, the pupils found it difficult to fully understand what was meant by life/social skills. We think that one explanation for this can be that the Swedish language has no word for life/social skill.

The pupils suggested that the DSAT could be developed to include activities or tasks that help to improve 21st century skills. We believe this is an important aspect when working with self-assessment. As Andrade (2019) argues, pupils should be given opportunities to work with corrections and adjustments. However, this is not possible in the current DSAT.

Finally, if self-assessment tools are to be used by pupils who are not used to performing self-assessments, they need to have the opportunity to practise. Exploring additional viewpoints from pupils, including aspects like setting goals, making plans, self-confidence, inherent curiosity, personal values, emotional reactions, and similar factors, was not within the scope of this current research. Nevertheless, incorporating these elements could offer a more comprehensive understanding of how pupils might react to the design and utilization of the DSAT or other analogous tools created for comparable intentions.

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Developing Spatial Literacy Through Designing Origami: Advancing Maker Education Pedagogy with Maker Études

Marten B. Westerhof, Technological University Dublin, marten.westerhof@tudublin.ie
Colm O'Kane, Technological University Dublin, colm.okane@tudublin.ie
Gavin Duffy, Technological University Dublin, gavin.duffy@tudublin.ie

ABSTRACT

Spatial literacy is crucial to success in STEAM-disciplines. Within these disciplines, spatial thinking manifests in a variety of ways, ranging from visualising how pieces of a solution might fit together to effectively communicating solutions to others through language, gestures, and graphic representations. Pedagogy for developing spatial literacy for children is still in its infancy, as training studies tend to focus on paper-and-pencil-based activities that resemble psychometric tests without explicit consideration for didactic approaches. Maker education offers children a design-based way of learning through a process of tinkering, designing, and building, with potential for creative output. In practice, educational maker activities generally tend to overemphasise prototyping tools and the development of the procedural knowledge required to use those tools. However, these hands-on learning activities could aid children to not only develop making skills, but also to attain spatial literacy. Although studies exist that identify spatial thinking during educational maker activities, no efforts have yet been made to design a maker activity that specifically aims to develop participants' spatial thinking holistically. This paper details a case study of the design and implementation of an origami workshop that aims to develop participants' spatial literacy. Origami, the art of folding sheets of paper into figures, is a process that requires frequent and varied use of spatial thinking. The workshop adopts the form of a 'maker étude', analogous to a musical étude, a satisfying exercise to practice and improve a particular technique so it can be applied creatively. The implementation of the origami maker étude in a public library makerspace in Amsterdam and its potential to support the development of spatial literacy are discussed. Finally, several suggestions are made for future research into the development of primary-school age children's spatial literacy in makerspaces.

Keywords: Maker education, spatial literacy, origami, design-based learning, STEAM

10. INTRODUCTION

The ability to manipulate and transform mental representations of objects in space is an essential component of success in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Wai et al., 2009). Spatial ability is malleable, with several studies highlighting the positive effect of pedagogically-sound training interventions on children's (Hawes et al., 2017; Lowrie et al., 2017) and adults' (Sorby, 2009) performance on psychometric tests. Training spatial ability is effective at the early stages of children's educational careers, when training can positively impact much of a child's educational career, and is particularly important for a cohort of children who have received much of their education online due to the COVID-19 pandemic (Lane & Sorby, 2022). However, the diverse forms of spatial thinking that are used in STEM disciplines are not covered by the psychometric construct of spatial ability (Atit et al., 2020), resulting in a reductionist understanding of spatial thinking. Furthermore, current educational efforts are often held back by the fact that training studies overemphasise the psychometric factors of spatial ability in the interventions (Bower & Liben, 2021), and rarely consider pedagogy explicitly (Adams et al., 2022). More holistic conceptualisations of spatial thinking within these disciplines are sparse, but several examples exist in work by Ramey and Uttal (2017) and Lane et al. (2019). Ramey and Uttal (2017) conceptualise spatial thinking within STEM not just as internal cognitive processes, but as 'repertoires of practice' that are mediated through context and supported by the use of tools, representations, and collaborations between participants. Spatial literacy is conceptualised as a set of skills one needs to engage in STEM disciplines, consisting of the ability to visualise, reason, and communicate about spatial concepts (Lane et al., 2019). Such conceptualisations of spatial thinking in STEM provide a better basis for designing didactically-sound interventions and its conceptualisation as a form of literacy gives a strong educational imperative. Zhu et al. (2023) conclude from an extensive analysis of the literature that spatially complex STEM problems could be useful for developing students' spatial thinking. In maker education, children learn in rich design-based learning settings through a process that emphasises tinkering, designing, and building. Maker education could thus be a powerful medium for developing spatial literacy by providing children with spatially complex STEAM (STEM + Art) activities to practice their spatial visualisation, reasoning, and communication skills. Maker education also provides room for the extensive manipulation of objects in space e.g., by creating three-dimensional representations of ideas, which is crucial for children to learn to visualise and reason about spatial concepts (Yang et al., 2020). This paper details the development and pilot case study of the implementation of a theoretically informed origami workshop that aims to support the development of primary school-age children's spatial literacy and discusses the workshop's feasibility within the context of public makerspaces in Amsterdam.

11. LITERATURE REVIEW

11.1. Spatial thinking in origami

Origami is the Japanese name for the art of folding paper into figures. Due to widespread attention and innovation in origami over the course of the 20th century, it has sparked new applications in STEM-disciplines such as aeronautics, micro-engineering, and architecture (Meloni et al., 2021). Origami is also extensively used for educational purposes and, for example, its use in teaching mathematics is well-developed, as illustrated by books such 'Project Origami: Activities for Exploring Mathematics' by Thomas Hull (2013). Folding origami requires visualising of and reasoning with spatial concepts, e.g., in translating verbal and graphic instructions onto the paper, and rotating, inverting, and visualising how a sequence of folds results in a completed model (Taylor & Tenbrink, 2013). A 2014 study from Turkey describes the effect of a series of origami activities that were embedded in mathematics classes on the spatial thinking of 9–12-year-old students and found that it had a statistically significant effect on the students' spatial visualisation and spatial orientation test scores (Cakmak et al., 2014). Findings by Taylor and Tenbrink (2013) suggest that spatial training that includes vocabulary for spatial concepts, such as those found in origami, may help to build spatial thinking, as they found that the use of 'new spatial terms' correlated with success in origami related tasks. An origami and paper engineering programme for elementary school-age children resulted in gains in the participating children's spatial thinking, and it was found that the engagement increased, particularly from girls, which may make origami a good medium to help close the gender-based performance differences observed on some tests of spatial ability (Taylor & Hutton, 2013).

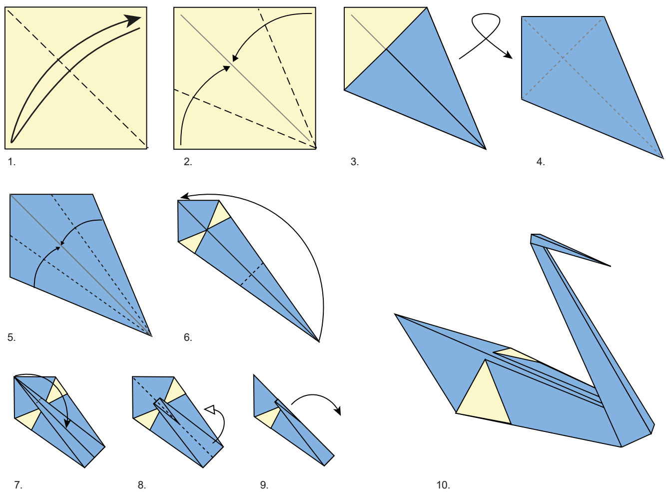
11.2. Pedagogical considerations for the makerspace

Within makerspace settings, activities generally revolve around a playful process of iterative problem solving in open-ended design tasks (Blikstein, 2018). The context of this project is within the makerspaces of the *Openbare Bibliotheek Amsterdam* (OBA), the public library of Amsterdam, The Netherlands. In these makerspaces, coaches offer both in-school and after-school programmes consisting of weekly afternoon-long workshops. Over the course of such a programme, children make e.g., their own stuffed animals or automata using prototyping tools such as laser cutters, 3D-printers, and sewing machines. These educational maker activities tend to be rather result-oriented, as coaches focus on helping children create something they are proud of, but as a consequence lose out on the potential to scaffold the children's learning processes. This is illustrated by Pijls et al. (2022), who found that the makerspace coaches in the OBA hardly mentioned evaluating the children's activities and work during these workshops. To advance the pedagogy of the activities in public library makerspaces in Amsterdam, a conceptual format was developed to design activities that are more learning-oriented, with specific emphasis on spatial literacy. Inspiration was taken from the musical 'étude', which is a composition that explores a technical problem in a musically coherent and aesthetically satisfying way (The Editors of Encylopaedia Britannica, 2011). An étude is thus a tool to further a specific technical skill through a cohesive exercise that is aesthetically pleasing, gives a sense of accomplishment after completion, and teaches techniques that can be used for creative expression and improvisation. These principles were transposed to an origami maker étude, consisting of a two hour-long workshop in which children first practice origami techniques and then creatively apply these newly acquired skills to create a novel design.

11.3. Origami maker étude for developing spatial literacy

The workshop's structure follows the format of the activities in the OBA makerspaces and its contents were informed by studies of origami activities that have shown to improve psychometrically assessed spatial ability and to facilitate the use of spatial language (Cakmak et al., 2014; Taylor & Hutton, 2013; Tenbrink & Taylor, 2015). In the first half, a brief plenary introduction to origami techniques is given, followed by step-by-step instructions for traditional origamis such as the relatively easy swan and more complex crane models. These instructions are illustrated through diagrams and symbols, standardised in the Yoshizawa-Harbin-Randlett system, which show the linear sequence of transformations the paper needs to go through to recreate the final design (Lang, 2012). For about 45 minutes, the children explore how to fold classic origami designs using instructions on a handout, while they discuss and help each other.

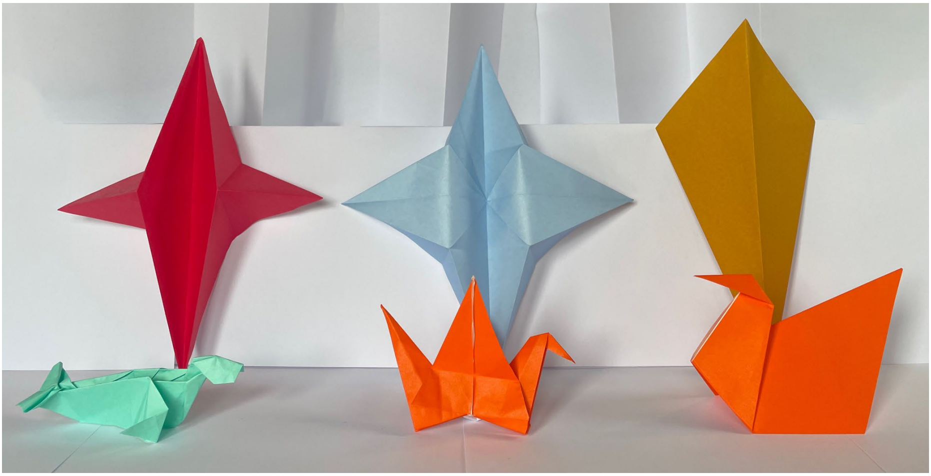
Figure 48.
Origami Instructions for the swan model



This is followed by a plenary discussion in which the children share their experiences of folding. After a short lemonade break the children exploratorily design a novel origami for another 45 minutes to an hour. This workshop section was informed by Chapter 4 of the book 'Origami Design Secrets' by Robert Lang (2012), and a course on YouTube by Brandon Wong (2022) based on the book by Lang. The children are introduced to three 'classic' origami bases (Lang, 2012) – the fish, bird, and kite – and shown several different origami designs based on each.

The workshop facilitator then explains that many classic origami designs were made by manipulating the flaps on these bases e.g., to resemble different animals. The children are first split into small groups of 3 - 4 and tasked with thinking of animals that they could create from each of the bases. After coming up with several possible designs, they transform one of the classic bases using 'detail folds' (Lang, 2012), in a process analogous to music improvisation, where techniques are creatively applied after having practised them. Finally, the children present their designs to each other, and are tasked with recognising the bases in the origami designs folded by their peers. The children then organise the designs based on different aspects such as orientation, what they represent, simplicity, complexity, etc., and discuss which designs they liked most or found surprising.

Figure 2.
From left to right: a fish, bird, and kite base with respective design examples in front.



12. METHODOLOGY

This paper describes a case study of the implementation of the origami workshop in the context of an OBA makerspace, with specific interest in its feasibility and potential to support the development of spatial literacy of participants through practice. Whereas most workshops are hosted by the makerspaces, in this case the first author acted as workshop host. The first author had observed several workshops and discussed their didactic approaches with the coaches at several stages during the iterative process of developing the origami workshop. The workshop replaced the regular programming of the makerspace. The goal of the case study was principally centred on the workshop's feasibility and pedagogical qualities. Data were collected through observations and photographs and analysed by the first author. A week after the workshop, an informal debriefing with the coaches took place to reflect on and discuss the implementation and structure of the workshop.

12.1. Participants

The workshop was attended by 12 children of primary school-age, six girls and eight boys, and two boys in the first year of secondary school. The primary school-age children all regularly attend the after-school workshops on Wednesday afternoons. The two older boys originally came to finish a 3D print that they had started during an in-school programme earlier that day but decided to join the workshop. The two makerspace coaches had dynamic roles, in which they worked on origami designs themselves, supported the child participants in their origami folding, and helped the first author to host the workshop.

13. RESULTS

When the children had arrived, they were asked to sit down around a table in the centre of the room. The first author introduced himself, the structure of the workshop, and asked the children several questions about their experiences with origami. After some basic origami techniques were explained, such as valley and mountain folds and the importance of folding neatly, the children received handouts with folding instructions. All children succeeded in folding the swan from the instructions, but most of them needed help with deciphering the diagrams, with several children waiting for the facilitator to explain each step to them. Two girls decided that they would fold swans in all available colours. When asked by the first author if they would also like to try folding the crane, a more challenging model, they responded no, and both girls spent most of the workshop folding a rainbow of origami swans. Two boys, who had indicated at the start that they would prefer to work on their own projects rather than folding origamis, quickly and independently finished their swans, and then grabbed their laptops, 3D modelling in TinkerCAD and playing video games for the remainder of the workshop. After having finished the swan, most other children tried to fold origamis from the instructions. One boy asked for help from the first author to help him fold the fish and bird base from the instructions in the handout and managed to recreate one of the examples designed by the facilitator from the fish base independently. After about 45 minutes, all children had stopped folding origamis and the makerspace coaches organised a lemonade break for the children.

Figure 3.
Folding swans from instructions during the first half of the workshop.

After the break, the first author asked the children about their experiences during the first half of the workshop, such as what they noticed while they were folding. The second half of the workshop was introduced by explaining how classic origami bases, such as the kite, fish, and bird can be used to design novel origami that represent animals by performing detail folds on the flaps. The children were then asked to start the process of doodling, but several of them grabbed their laptop instead of trying this step. Rather than bring them back to doodling, one of the makerspace hosts quickly looked up an instructional video for making an origami elephant, which she displayed on the large TV-screen in the makerspace. The children followed the steps in the video, which was paused every now and then so they could catch up. Some of the children noticed that this elephant origami was designed from the bird base too, which they had folded earlier in the workshop. The boy who had recreated one of the examples earlier, noticed that an intermediate step of the elephant looked like a dinosaur, which he decided would be his final design as he preferred over the elephant. The presentation moment at the end was skipped, as the workshop had surpassed the scheduled time, and most children were being collected by parents. Before they left, two children independently asked the first author if they could take home the instructions and some origami paper to continue at home. One girl said: 'I love origami!'.

Figure 4.
Folding elephants from a video and trying to design novel origami from one of the bases.

14. DISCUSSION

14.1. Discussion of the workshop

Most of the children engaged with origami independently for about 30 to 45 minutes before they lost attention. In this period, the children freely explored the instructions that were given in the handout, but most children did require help from the facilitator. The workshop introduction should more clearly explain how to read diagrams and teach correct folding techniques through several examples. Additionally, more differentiation in difficulty is required from the start to mitigate the children losing interest from the activity either being too difficult or too easy. For example, providing instructions for other models that are more difficult than the swan, but less difficult than the crane could help to achieve this. The structure of the workshop was intended to scaffold the children's practice with origami techniques, each section being a step that built on the previous and leading up to an original design. However, the results from the pilot indicate that this structure was too linear and therefore untenable within this context. For example, too many moments seemed to require a shift from individual work to group-based instruction and vice versa, taking children out of their own processes. As a consequence, the workshop's structure failed to effectively scaffold the children's idea generation in the second half of the workshop. Instead of several short instruction moments spread throughout the workshop, one plenary brainstorm immediately after the break could help to support the children in coming up with what they want to make. The use of an instructional video from a first-person perspective helped many children who struggled, but the use of the video by the makerspace coach did undermine the process of constructing novel origami through doodling. Due to a lack of time, the presentation moment that was part of the original structure of the workshop did not take place. However, a conclusion to the workshop through a collective celebration of the children's creations is not only an effective way to bring the workshop to a close, but also an important step in consolidating learning through a reflection on the process and ups and downs the children experienced.

14.2. Discussion of the role of spatial literacy

The children's degree of success in following origami instructions varied greatly, as some kids were able to fold independently and successfully while others required extensive assistance, which could indicate that the individual levels of spatial literacy played an important role in the participants' success in the workshop. For example, most children found it much easier to follow the first-person perspective instructions in the video, which could be explained by the video requiring less visualising, reasoning, and perspective taking compared to translating the 2D diagrammatic instructions in the handouts into actions. During the second half of the workshop, which requires children to creatively apply their newly acquired origami techniques, some children demonstrated an ability to creatively see new things in intermediate steps origami, e.g., by changing its orientation. These findings illustrate the importance of one's ability to visualise, reason, and communicate about spatial concepts, i.e., being spatially literate (Lane et al., 2019), as well as the ability to translate spatial thinking into actions that are mediated through tools and materials (Ramey & Uttal, 2017). For children to attain spatial literacy through maker education, it is pertinent for educators to understand how they can support the wide variety of spatial practices that emerge in maker education contexts and how they can scaffold children's abilities to visualise, reason, and communicate about spatial concepts and relations. Through the theoretical lens of spatial literacy and spatial practices, an activity such as the one described provides a medium through which the interactions between participants and educators can be studied as they emerge based on different elements of activities and contexts.

14.3. Conclusion

This paper described the design and implementation of a workshop that follows the principles of a maker étude in which primary school-age participants learn to creatively apply origami techniques, with the specific aim of developing spatial literacy. Observations from the pilot indicate that a well-designed and implemented workshop can be used to elicit a variety of spatial practices, providing a valuable medium to investigate how activities and educators may support the development of spatial literacy within makerspaces. Through a future study, the making process of a number of children could be analysed for the diverse forms of spatial practices that emerge from maker education activities and how educators support these diverse practices within their makerspaces. This would provide a valuable step towards a better understanding of how children of primary school-age could develop spatial literacy during design-based maker activities and how educators can support them in harnessing this set of crucial skills while working on projects that are important and engaging to them.

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Augmented Reality to Support Self-directed Learning in Practical Technology Teacher Training: Presentation of the SelTecAR Project and Investigation of the Conditions for Success

Tobias Wiemer, Carl von Ossietzky Universität Oldenburg, tobias.wiemer@uol.de
Marius Rothe, Carl von Ossietzky Universität Oldenburg, marius.rothe1@uol.de

ABSTRACT

Augmented reality (AR) can be a useful tool to support self-directed learning processes. This possibility is being used in the SelTecAR project (Self-directed Learning in Technical Studies through Augmented Reality) by the Technical Education working group at the University of Oldenburg to improve the manual-practical training of technical education students and to consider more strongly that some students with previous experience can link to previously acquired skills, whereas the other students cannot. Therefor a new learning concept is being developed for the technology teacher training workshop module, which enables AR-supported self-directed learning with flexible learning times and assistance. Within the project, an augmented reality environment is created in the workshops where teaching takes place, in which students can use their own smartphones to view instructions as overlays or video tutorials and call up important information on tools or machines. For the purpose of scientific monitoring, support needs are determined in order to be able to set up the AR environment in a targeted manner; in addition, conditions for success in the use of the AR environment are investigated. The results of the self-directed learning needs assessment show that working with machine tools and circuit design are learning content areas that require support for self-directed learning. The investigation of the conditions for success in implementing such an environment happens within the development. Several points became apparent. Among other things, the selection of the right software plays a major role depending on the support needs. In addition, access must be low-threshold (use of the private smartphone, without login, etc.) and the use must be integrated into the instruction phases preceding the self-learning phases.

Keywords: Augmented Reality, self-directed learning, technical education student, manual training

1. REPRESENTATION

1.1. Initial situation

The engagement with technology in technology education often occurs in a hands-on and product-oriented manner (Bleher, 2001). Typical methods of technology education are construction and manufacturing tasks (Hüttner, 2009). The classroom where the lessons are held should possess a workshop character. This allows for testing manual skills and for the use of various materials such as wood, metal, and plastic. Furthermore, the characteristics of a laboratory should be present for conducting technical experiments and analyses (Röben, 2018).

In order to enable prospective technology teachers to teach in such an environment, competencies for practical work with tools and machines must be acquired during teacher training. According to Geschwendtner & Geißel (2018), these competencies include "solid and applicable knowledge of relevant materials, tools, measuring instruments, machines, safety-conscious handling of tools and machines, maintenance and care, as well as (2) practical skills (manual skills)." In the teacher training programme at Carl von Ossietzky University Oldenburg, this knowledge is taught in a basic module that comprises twelve semester hours. Teaching in this module takes place in small groups with alternating lessons and self-learning phases. The taught skills are repeatedly addressed in project-oriented modules throughout the further course of study.

1.2. Problem statement

At the start of their studies, the prior manual experience of students varies significantly. Some students have completed vocational training before commencing their studies, whilst others have not. This was found in a survey at several locations of teacher training programmes, including the University of Oldenburg (Bünning et al., 2018; Riese & Ermel, 2022). Moreover, there are only a few projects that offer technology education at the gymnasium level in Lower Saxony (Wiemer & Haverkamp, 2020), so only those students who had prior experiences beyond a purely academic education can generally build on them.

As a result, there are key challenges in technology teacher training: While students with manual experience can build upon already acquired skills in practical modules, others cannot. Furthermore, there is a need to reactivate acquired competencies in later project-oriented modules, but this is often postponed.

1.3. The SelTecAR-project as a solution for the problem

The SelTecAR project was developed to create an AR environment promoting self-directed learning. It is supported by the "Freiraum 2022" call for proposals from the Foundation for Innovation in Higher Education (Stiftung Innovation in der Hochschullehre, 2022).Within this project, a new learning concept for the workshop module is being developed for technology teacher training at the University of xxx. This concept enables AR-supported self-directed learning offering flexible learning times and assistance, tailored to individual learning needs. Furthermore, these aids are intended to be utilised throughout the course of study to address individual knowledge gaps in follow-up modules.

As a component of the project, an augmented reality environment is being established in the workshops where teaching occurs. Students can use their smartphones to view instructions as overlays or video tutorials. They can also access crucial information about tools (e.g., screwdrivers, side cutters, soldering irons) or machines (e.g., lathes, jointers, laser cutters). This new approach reduces instructional phases by lecturers and extends individual self-learning phases in the workshop module, allowing students to decide which areas require more information and repetition through the AR environment.

The project's objectives include: development of an AR environment with explanatory overlays and video tutorials for the workshops, development of a seminar sequence adapted to the workshop module and scientific monitoring and evaluation of the implementation.

To fulfil these objectives, machines, tools, and processes that require a high level of explanation are initially identified through surveys of students and teachers. This is followed by restructuring the seminar sequence in terms of instructional and self-learning phases. Simultaneously, a survey is developed and conducted for students participating in the workshop module without AR support. Subsequently, information packages and video tutorials are created for the identified content, and an AR environment is set up for retrieval. Upon completion, internal training of the research group members on using the AR environment takes place. The AR environment will be applied within the restructured workshop module in the summer semester 2023, along with scientific oversight examining its use by students.

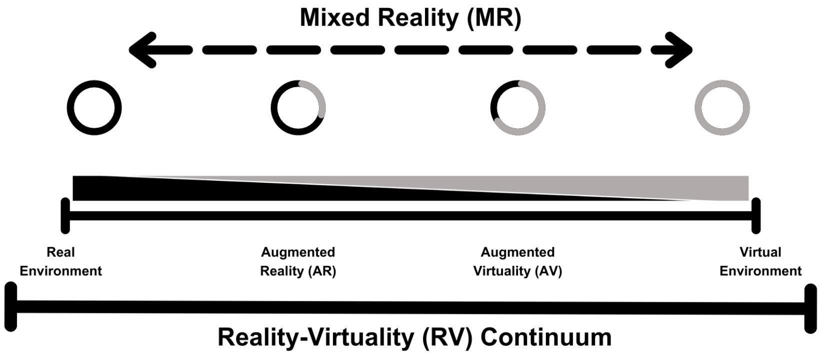
2. THEORETICAL BACKROUND AND PRELIMINARY SURVEY

2.1. Augmented Reality

The technology education of tomorrow requires teachers to integrate forward-looking topics such as 3D printing, robotics, and new technologies, media, and methods into their lessons. Virtual worlds, in which learners can explore technical objects, spaces, and places, should increasingly be part of today's technology teachers' task repertoire (Nepper, 2021).

Augmented Reality (AR) is often used interchangeably with Mixed Reality (MR) and Virtual Reality (VR). Milgram et al. (1994) established the Reality-Virtuality Continuum to clarify these terms. The continuum signifies a gradual transition between real and virtual environments (Mehler-Bicher & Steiger, 2022). Reality is at one end, and virtuality is at the other. The transition between them is MR. AR is part of MR, but not all MR is AR. The distinction lies in the degree of overlay. AR dominates when reality prevails, while Augmented Virtuality (AV) dominates when virtuality prevails (Milgram & Kishino, 1994).

Figure 49.
The Reality-Virtuality Continuum own illustration based on Milgran et al. 1994, S.283



Azuma (1997) defines AR as overlaying reality with virtual objects, complementing reality instead of replacing it entirely. AR is characterized by combining virtual and real environments with partial overlays, real-time interaction, and three-dimensional relationships between virtual and real objects. AR can be divided into a broader sense, which only includes the extension of reality with virtual content, and a narrower sense that fulfills all three characteristics (Dörner et al., 2019; Mehler-Bicher & Steiger, 2022).

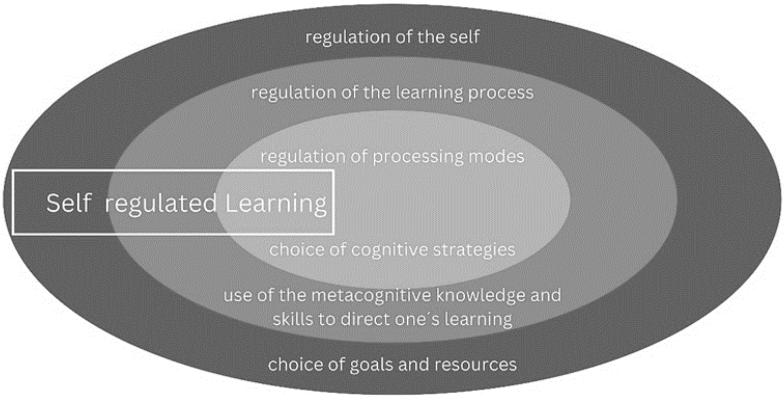
In the context of teaching and learning, AR can be applied in multiple instructional dimensions. A distinction can be made between learning with AR and learning through AR. Learning with AR means that learners use an AR environment to stimulate their learning processes. Learning through AR involves learners creating an AR environment to encourage their learning processes. The SelTecAR project can be considered learning with AR from the students' perspective, and learning through AR from the employees' perspective, as the environment must be built and implemented.

2.2. Self-activity in learning

According to Klafki (2007), self-activity is the central form of education, and the purpose of education is to enable self-determination. Self-determination includes self-regulated and self-directed learning. While these terms fall under the category of self-determination, they can be distinguished in the context of learning. Self-regulated learning is divided into three levels in Boekaerts' (1999) Three-Level Model of Self-Regulation: regulation of processing, regulation of learning, and regulation of self. Bastian (2007) adapted these levels to the terminology of planning, monitoring, and reflection.

Self-directed learning requires highly structured self-learning materials. These materials structure learning paths but do not prescribe them. It is not intended to relieve teachers of responsibility for the learning process, but to provide meta-competencies that enable learners to respond to new demands. Firstly, learners must develop an appropriate self-understanding in their capacity as learners. This self-understanding includes a corresponding role understanding in the institutional learning context, a willingness to take conscious responsibility for one's own learning process, knowledge of one's own learning patterns and behaviors, and the ability to use individual preferred learning strategies effectively.

Figure 2.
The Three-Level Model of Self-Regulation (Boekaerts 1999, S. 449)



AR support is situated in the field of self-directed learning, as it can be used to offer students additional support options that they can use independently to react to and solve new challenges. It must be ensured that learners are offered as many different learning paths and media as possible.

2.3. Preliminary survey on support needs

Creating an AR environment to support self-directed learning requires identifying the areas where students need assistance. This involves analyzing the module contents and surveying students to determine which topics they find challenging.

Therefore, a questionnaire was used to collect data from students in workshops, where they learn to operate various machines and tools. The questionnaire included a four-point Likert scale for self-assessment of support needs (Porst, 2014). The data were analysed employing descriptive statistics and box plots. Bivariate correlations were utilised to probe the relationship between the level of study and support needs.

The results showed that the average level of support needed was 1.43 out of 4. The highest level of support was needed in the area of automated manufacturing, with the widest range of support needs observed in the area of electrical engineering. The highest support needs were observed for the laser cutting machine and 3D printer, and for circuit building in electrical engineering. Female students reported significantly higher levels of support needed compared to male students. No significant differences were observed between bachelor and master students. These findings can be used to develop an AR environment to support self-directed learning, with a focus on addressing the support needs identified in the study (Autor 1 & Autor 2, 2022).

2.4. Conditions of success as a measurable construct

If educational research is practice-oriented, it should investigate whether an innovation in the field of education succeeds (Gräsel & Pachmann, 2004). The conditions for success are diverse. In general, two models can be distinguished when implementing innovations in education, and accordingly, two different approaches can be assigned to investigating the conditions for success (cf. ibid.). The first approach is a top-down strategy. In this method, responsible authorities (such as researchers and education officials) determine the innovations and hand them over for implementation. Measurable success factors are whether the innovations are implemented and to what extent the implementers make changes during implementation. Another approach is the symbiotic implementation strategy. Here, the innovations are developed in cooperation with the implementers and introduced together, and may be further developed in the process. Measurable success factors are the improvement of the situation to be changed and the success of the cooperation of the participants (cf. ibid.).

To successfully implement a project, potential influencing factors on implementation should be considered in the development process (cf. Schulte & Wegner, 2021). These can also provide indications of appropriate research questions to investigate the conditions for success. Jäger identifies three factors for this purpose (Jäger, 2004). The first is the content factor. An attractive innovation project forms an advantage over the previous practice, corresponds to the values of the implementing teacher, and is not too complex. The second factor is structure. This refers to the relationship between the goal and the initial structure, which ideally should not be too far apart. The third point is the people, whose cooperation and interaction are a success factor in the implementation of innovations.

In summary, it can be stated that conditions for success are a measurable construct for the implementation of innovations. How they're investigated varies based on the implementation type. The decisive factors for this are content, structure, and people.

3. INVESTIGATION OF SUCCESS CONDITIONS

3.1. Research Questions

Generally, the question is whether the system has been successfully implemented, which leads to the first research question, "How did the roll-out succeed?" (Q1). The other questions relate to the points mentioned in 2.4 regarding the conditions for success: In terms of person, these include the question, "Are lecturers regularly referring to the AR environment and allowing appropriate time for self-learning phases?" (Q2) concerning content: "Is the AR environment used to support self-directed learning processes?" (Q3) and to the area of structure, the question, "Which areas of the AR environment's structure are used preferentially?" (Q4).

3.2. Research Design

In order to measure the success of the implementation of the AR environment to support self-directed learning processes, a research design has first to be developed. Based on design-based research projects, where innovations are implemented in a regulatory process (Baumgartner et al., 2003), there should still be opportunities for adjustment during the implementation. To ensure this, a two-stage survey was planned. The first survey point is six weeks after the start, after which there is an opportunity to readjust and the second is eight weeks later, just before the end of the semester.

The project examined here can be considered a top-down implementation in relation to Chapter 2.4. Although the teachers in the training workshops participated inthe selection of content for the AR environment, the implementation was planned by the project managers and presented to the teachers for implementation. In terms of the three conditions mentioned in 2.4 - content, structure, and people - it must therefore be examined in the content area whether the AR environment is used as planned, i.e. to support self-directed learning processes. In terms of structure, the functional integration of the AR environment into teaching must be assessed. This involves determining whether students can effectively use the mobile application (app), identifying which sections of the app are frequently accessed, and recognising any issues related to its use. In the area of people, it must be examined whether the teachers regularly point out the app and whether they also allocate times to work with the app. Since there is only a moderate amount of experience gained at the first survey point, especially in the area of use, it is also asked to what extent the students plan to use the app in the future. For this reason, for the first survey presented here, the last two questions (Q3 and Q4) are asked as forecast questions of future usage, which can then be compared with actual usage behavior after the 2nd survey.

3.3. Methodology and Sample

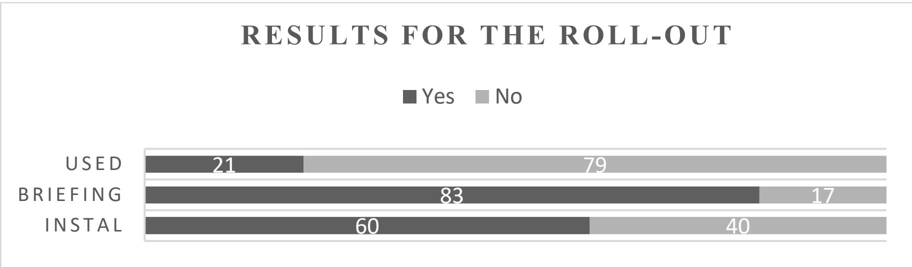
To gather a comprehensive database, all students participating in the workshops will be surveyed. The sample thus consists of all students of one year, so approximately 70 people can be surveyed. For the survey of such a large number of people, the use of a questionnaire is recommended (Döring & Bortz, 2016). The content of the questions are the items mentioned in 3.1. These are mostly assessment questions, such as the frequency of use of the app in different contexts. For such a type of question, the use of a Likert scale is suitable (Porst, 2014), which is constructed as an endpoint-oriented scale and can therefore be analysed with methods for interval-scaled data (Hollenberg, 2016).

Specifically, the questionnaire is structured as follows: firstly, participants are coded to allow for comparison across the two survey points. Then it is also asked how many workshop courses have already been taken and whether there is previous experience, for example through training. Afterwards, the questions about content, structure, and people are asked. The conclusion consists of questions about the estimated future use of the AR environment.

3.4. Results

Seventy students took part in the survey six weeks post-roll-out. The survey showed that 83% had received an introduction to the environment, 60% had already installed the app and 21% had already used the app (excluding the introduction) in the seminar for self-directed learning (see figure 3). For Q1, this means that the roll-out can be considered a success.

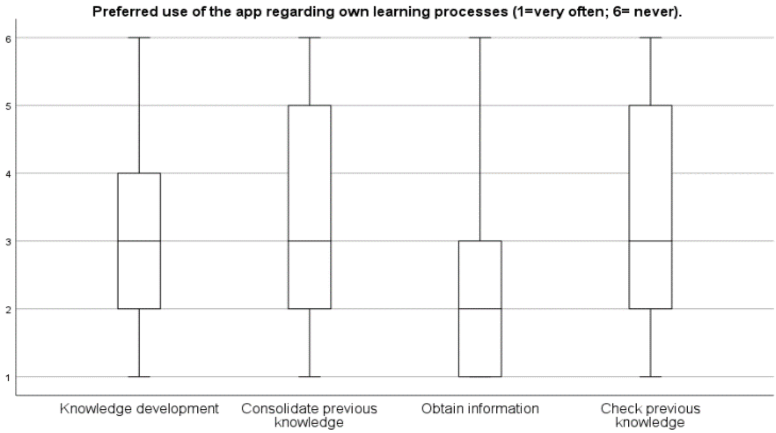
Figure 3.
Results for the Roll-Out



In terms of the restructuring (1= very often; 6= never), the questionnaire showed that the students are rarely pointed to the AR environment so far (M=4.53; M=5.00; SD=1.491). Additionally, students are currently still not given enough time for their self-study phases during the seminar (M=4.79; M=5.00; SD= 1.339). For Q2, this indicates that that consistent mentions of the AR environment, paired with dedicated self-study intervals, need enhancement. This may be related to the fact that only 21% of the students use the app so far.

As noted in 3.2, these questions are asked as prediction questions. This leads to the following results: Preferably, students would use the app to obtain self-directed information (M=2.71; MD=2.0; SD=1.687), followed by use for knowledge development (M=3.23; MD=3.0; SD=1.486). A broad spread observed in the box plot can be attributed to the initial roll-out phase and the ongoing innovation establishment.

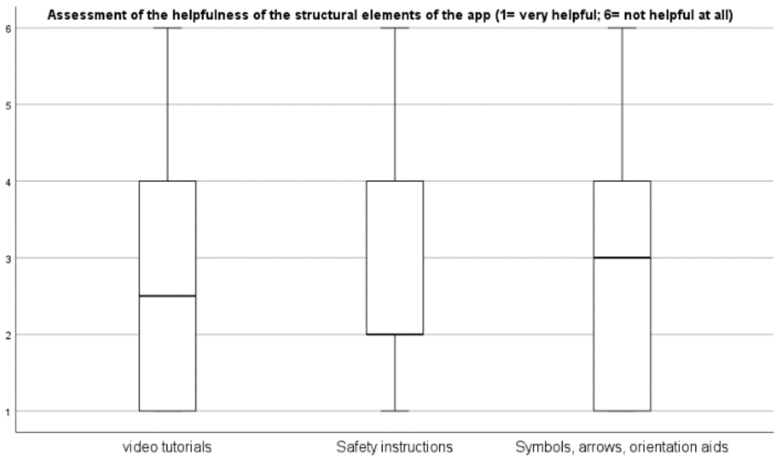
Figure 4.
Preferred use of the App.



For Q3, it thus emerges that students would use the AR environment mainly for obtaining information and acquiring knowledge with regard to their self-directed learning.

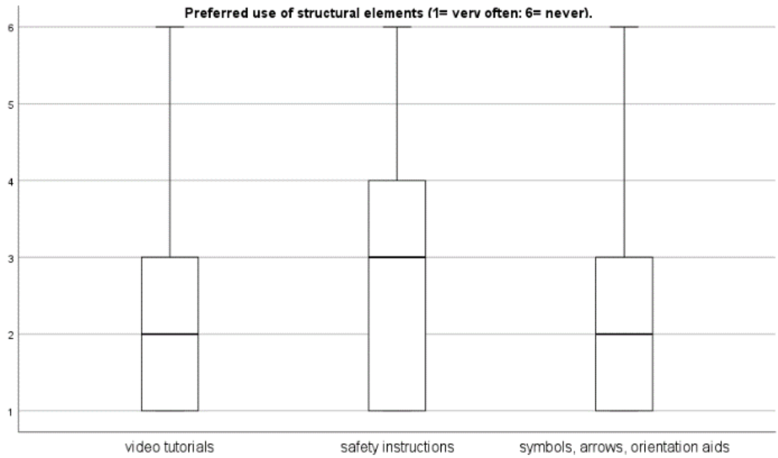
At the structural level, all three structural elements are rated as equally helpful, with video tutorials slightly predominating (videos: M=2.74; MD= 2.5; SD= 1.603; safety instructions: M=2.80; MD= 2.0; SD= 1.575; icons: M= 2.79; MD= 3.0; SD=1.623).

Figure 5.
Assessment of the helpfulness of the structural elements



The students would prefer to use the video tutorials (M=2.51; M=2.00; SD=1.549) as well as the symbols, arrows and orientation aids (M=2.53; M=2.00; SD= 1.683). Here again, there is a large spread in both, which can also be attributed to the roll-out and the innovative character

Figure 6.
Preferred use of structural elements



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Q4 suggests that while all AR environment's structural components are deemed beneficial, students are inclined towards incorporating video tutorials and illustrative symbols and aids in their autonomous learning journey.

4. CONCLUSION

Augmented Reality can be used to activate self-directed learning processes by providing individual support needs to students through an AR environment. Whether the implementation of an AR environment is successful depends on the factors content, structure and people. The results of the study presented here on the conditions for success show that the roll-out worked well and that the first students also used the AR environment. The potential that the students see in the app can be highlighted as positive at the content and structural level. For example, students want to use the app to obtain information and acquire knowledge in a self-directed manner. To do this, they would prefer to use video tutorials as well as the icons, arrows and orientation aids. After the roll-out phase, however, there is still room for improvement in terms of compliance with the new seminar structure. For example, the data shows that too little time is still allocated for this and also that too little attention is still paid to the AR environment. For this reason, the next steps within the project consist of intensive support for the transformation of the seminars. This result also shows that a key condition for the successful implementation of a new technology is the successful restructuring of the seminars in which it is to be used.

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What Attracts Children to Computer Science?

Jessica Yauney, Brigham Young University, jessica.yauney@gmail.com
Scott Bartholomew, Brigham Young University, scottbartholomew@byu.edu

6 ABSTRACT

Significant effort is being committed internationally to promote computer science (CS) learning in K12 classrooms. Career & Technical Education and Design & Technology courses are two of the most common targets for increased CS instruction. "Hour of Code" (HoC) is one example of the tasks teachers are asked to implement, devoting one hour annually to complete pre-developed CS activities with their students. Researchers collected data from students before and after engaging with an HoC activity and investigated students' motivation, or lack thereof, around coding. Specifically, all students were asked why they would or would not like to learn more about coding following their participation in the HoC activity. Several key findings emerged from the analysis of the student comments. These findings, as well as practical classroom implications, will be shared with an emphasis on trends in student's preconceptions and future interest in CS. Additionally, our examination of students' interest in coding as it relates to "fun" and "job prospects" was explored, as well as students' associated concerns. The role of K12 education as it relates to career preparation is one that can provide greater insight for all technology teachers as they approach CS and other subjects like engineering and design. These trends are aligned with the integration and implementation of the HoC activities in classrooms. Thus, this research has practical significance and can inform future efforts aimed at increasing student interest.

Keywords: Computer Science Education, Hour of Code, Student Perceptions.

1. INTRODUCTION

Educators, policymakers, and other leaders are currently working to expand computer science (CS) education for various reasons. CS is a growing career field where demand exceeds supply (New Data: AP Computer Science Principles Course Bringing More Diverse Set of Students into Computer Science Pipeline, 2020) and where diversity is a priority. "Hour of Code" (HoC) is one of the largest programs created toward this goal with over $90 million USD in funding (Code.org 2018 Annual Report, 2019) and millions of classroom hours devoted per year (Code.org 2018 Annual Report, 2019).

CS education programs and their effectiveness are of interest to Design & Technology (D&T) educators and other leaders for two reasons. First, D&T educators are increasingly being asked to include CS concepts in their courses. Second, many attitudes and motivations that influence students in CS are mirrored in other career focused education programs like D&T.

6.1 Hour of Code

The primary objectives of the Hour of Code (HoC) initiative include the promotion of awareness and interest in the field of CS (Majumdar, 2018). HoC offers a diverse range of one-hour activities explicitly designed to facilitate students' learning in computer science, eliminating the requirement for teachers to possess technical expertise. These activities encompass various themes, difficulty levels, and programming languages. Although HoC serves as a significant catalyst for fostering student interest, it primarily serves as an introductory platform.

The Hour of Code program curates an extensive catalogue of activities that can be utilized by teachers and students alike. These activities can be carried out using computers, tablets, or even without electronic devices. The available activities include self-led tutorials, as well as comprehensive lesson plans that can be incorporated into a teacher's instruction. Each activity is categorized by grade level and difficulty and can be sorted based on popularity or recommendations. Notably, at the time of this research, activities entered around the popular game Minecraft were particularly popular. Four distinct Minecraft-themed tutorials were made available to students as part of this research, allowing students to choose their preferred activity with some students completing a tutorial and proceeding to embark on a second activity and other students only partially finishing a single tutorial.

In-house data collection efforts by HoC creators claimed that engagement in HoC activities leads to enhanced student attitudes towards computer science and heightened interest in the subject (Phillips & Brooks, 2017). Nevertheless, a dearth of evaluation pertaining to the effectiveness of this initiative remains evident. Out of the 64 identified papers focusing on the Hour of Code, merely 12 of them involved research experiments that investigated the outcomes of HoC, with the majority of these studies concentrating on non-K12 audiences (Yauney, Bartholomew & Rich, 2021). Although some research has begun examining the knowledge acquisition facilitated by students' participation in HoC activities, preliminary findings suggest limited development of programming skills (Du & Wimmer, 2015).

6.2 Computer Science and Design& Technology

Computer science and Design & Technology (D&T) education share several fundamental similarities, as both disciplines emphasize problem-solving, creativity, and practical application of knowledge. Firstly, both computer science and D&T involve a problem-solving approach that requires students to identify, analyse, and devise solutions for real-world challenges. In computer science, students are trained to break down complex problems into smaller, manageable components and develop algorithms or programs to address them. Similarly, in D&T, students engage in the design process, where they identify design problems, generate ideas, and create prototypes to solve those problems.

Secondly, both computer science and D&T foster creativity and innovation. In computer science, students are encouraged to think critically and creatively to develop novel solutions and optimize existing systems. They engage in algorithmic thinking and computational creativity to devise efficient and elegant solutions to problems. Similarly, in D&T, students are involved in the design and creation of functional and aesthetically pleasing products. They explore innovative design concepts, materials, and manufacturing techniques to bring their ideas to life. Both disciplines promote a mindset of exploration, experimentation, and the generation of original ideas.

Furthermore, both computer science and D&T emphasize the practical application of knowledge and skills. In computer science, students not only learn theoretical concepts but also apply them in coding and programming projects. They build software applications, develop websites, or work on data analysis tasks to see the direct outcomes of their coding skills. Similarly, in D&T, students engage in hands-on activities, using tools, materials, and processes to create physical artifacts or systems. They learn about structural integrity, mechanisms, and materials properties by designing and constructing prototypes. Both disciplines provide students with opportunities to apply theoretical concepts in practical contexts, enabling them to develop tangible outcomes and gain a deeper understanding of the subject matter.

Computer science and D&T share many of the same educational challenges as they seek to teach complex computational thinking skills, balance career application versus general education and preserve creativity while introducing a complex novel skill. By recognizing these similarities, educators can identify synergies between computer science and D&T education, fostering interdisciplinary connections and promoting learning for students.

6.3 Computer Science Motivation

Educators and other adults have formed many beliefs around what can and should attract students to computer science. Many people believe the increasing prominence of technology in students' lives has heightened the appeal of computer science. The rationale follows that the allure of being able to create, manipulate, and innovate with technology motivates students to explore the field of computer science. Others believe the chance for lucrative career opportunities leads students to computer science. They believe students are aware of the rewarding job prospects and financial stability that can come with a computer science degree. Still others believe the creative and problem-solving aspects of computer science are intrinsically appealing to students as computer science offers a platform for individuals to exercise their creativity and turn innovative ideas into reality. Others believe that, at least for some students, the inclusive and collaborative nature of the computer science community is attractive as computer science encourages teamwork, knowledge sharing, and open-source collaboration.

These ideas while commonly held, are not all supported by research finding. This report of a quasi-experimental study seeks to present the motivations claimed directly by students to support or question these assumptions to improve educators' ability to attract and retain students to CS fields and potentially apply these findings to D&T classrooms.

7 METHODS

7.1 Hour of Code Intervention

Over 2000 7th grade students participated in an HoC activity facilitated by the authors. After collection of associated permission forms, pre-test data and post-test data were successfully matched, and data was successfully analysed from 719 students (72 classes, nineteen 7th grade teachers, fifteen schools, four school districts) in the Western United States. To ensure students were representative of the wider school population, research was done with students enrolled in a required middle school D&T course which covers multiple D&T topics including computer science. Given that the teachers have historically covered CS topics variety of ways, Hour of Code was selected as the intervention for this study because it was the most common tool previously used by teachers. HoC is seen as particularly useful because it requires limited specific CS knowledge and training to facilitate. Many locations, including these districts, rely heavily on D&T teachers without specific CS training to provide computer science instruction (Yauney, 2022). The author who led these activities is a full-time professional software developer, former high school CS teacher and middle and high school CS teacher trainer.

All students were given one class period to complete the pre-survey, HoC activity, and post-survey. This time of these classes ranged from 50 minutes to 70 minutes based on the school schedule. Some students only completed the online HoC activities, while others completed online activities and then participated in a group discussion ranging from 5 to 15 minutes before completing their post-survey.

7.2 Student Survey

In student surveys, administered before and after completing the activities, students were asked on a 5-point Likert scale from strongly disagree to strongly agree if they “would like to learn more about coding in the future.” Students who agreed with the statement were then asked, “Why would you like to learn more coding in the future?” and students who disagreed were asked, “Why would you prefer not to learn more coding in the future?” For the sake of these analyses, only students’ agreement or disagreement with the statement was evaluated because it triggered this difference in secondary questioning. Further analysis of students’ full Likert responses, which is beyond the scope of this paper, would be possible using more advanced statistical models like the McNemar-Bowker Test.

7.3 Response Coding

Student responses were coded using thematic coding techniques following recommendations from Saldaña (2013). Initially each of the pre-survey responses was summarized by a series of single word themes. For example, “it looks boring”, “Because coding isn't my thing and I kind of think it’s boring” and “because I just kinda think it is boring” were all coded as “BORING.” Other statements were coded as several topics. For example, “Because it seems boring and takes forever. Even coding a Sphero was difficult and a long process” was coded as “BORING” and “HARD.” After initially coding all responses, themes that were highly similar were collapsed into one category (e.g., “stress,” “anxiety,” “pain” and “headache” were collapsed into one category, "PAIN". While many themes were unique to either positive or negative responses, some themes were used in both categories. This single-word thematic coding process allowed researchers to draw broad conclusions about students' overall thoughts. The use of such an open-ended question in a context where students have limited time and are motivated to complete the task quickly does however have limits on its validity given that some students engaged in inauthentic behaviours including copying the responses of their peers. Researchers heard students ask peers for their answer and then copy it but chose not to interfere with this behaviour. Additionally, while researchers acknowledge the potential for deeper qualitative analysis, this was not completed as part of this research effort.

8 RESULTS

Understanding students' initial motivation before interacting with the HoC activity provides valuable information regarding students' independent motivations and will be discussed first. The shift in student responses following engagement in the activity is then presented. This analysis both provides information about the impact of this activity and the potential for similar activities to impact student motivation.

8.1 Initial Thoughts

Initially 169 students (24%) expressed interest in learning more coding in the future and 540 students (76%) expressed a lack of such interest. All categories are presented in Table 1. Sadly, several types of responses cannot be interpreted. Some students answered YES, NO, or MAYBE; others said they did not know (IDK); others explained they had answered the previous question WRONG. The five most common explanations for student interest in order were that it was fun (FUN), provided a good "JOB" opportunity, allowed for the creation and playing of games (GAME), allows for the building of products (BUILD), and that it is "INTERESTING". The five most common explanations for lack of interest are stronger interest in an "ALTERNATIVE" skill, not finding coding interesting (NOT INTERESTING), believing it is "HARD" or "BORING", and disliking working with a "COMPUTER". Other students expressed motivation or lack of motivation based on the impact coding would have in the "FUTURE", its usefulness (USEFUL, USELESS, HELP, NOT NEED), applications like robotics (ROBOT), applications (APP) and websites (WEBSITE), specific programming languages (LANGUAGE), and prior knowledge (ALREADY, NO EXPERIENCE) and successes (GOOD, NOT GOOD). Surprisingly some students provided difficulty (HARD) as an explanation for their interest and ease (EASY) as an explanation for lack of interest. Other explanations given for interest were a general interest in learning (LEARN), a desire to be "SMART", a belief coding is "COOL", the positive influence of a "MENTOR", and the potential to make "MONEY". Other explanations for lack of interest include the "TIME" requirement to learn, a lack of desire for a coding job (NOT JOB), physical "PAIN", a preference for outdoor environments (NATURE), a dislike of "MATH", or a belief that other jobs pay more (POOR PAY). Of additional note is the explanation given by some students that coding either matched or did not match their self-image (IDENTITY).

Table 28. Number of Student Comments in Each Category of Explanation in Pre-Surveys

Why?			**Why Not?**		
Category	**Number of Comments**	**Percentage**	**Category**	**Number of Comments**	**Percentage**
FUN	44	26%	ALTERNATIVE	108	20%
JOB	32	19%	NOT INTERESTING	93	17%
GAME	22	13%	HARD	70	13%
YES	20	12%	BORING	63	12%
BUILD	14	8%	NO	51	9%
INTERESTING	11	7%	COMPUTER	45	8%
FUTURE	10	6%	NOT FUN	31	6%
USEFUL	9	5%	NOT GOOD	26	5%
LEARN	9	5%	USELESS	25	5%
ROBOT	4	2%	YES	20	4%
SMART	4	2%	TIME	20	4%
MAYBE	3	2%	NOT JOB	17	3%
WEBSITE	3	2%	MAYBE	16	3%
LANGUAGE	3	2%	ALREADY	12	2%
COMPUTER	3	2%	IDENTITY	10	2%
COOL	3	2%	FUN	9	2%
ALREADY	3	2%	PAIN	6	1%
APP	2	1%	IDK	6	1%
HARD	2	1%	NATURE	5	1%
MENTOR	2	1%	WRONG	5	1%
MONEY	1	.6%	MATH	5	1%
HELP	1	.6%	USEFUL	2	.4%
GOOD	1	.6%	INTERESTING	2	.4%
WRONG	1	.6%	NO EXPERIENCE	2	.4%
IDENTITY	1	.6%	NOT NEED	2	.4%
			EASY	1	.2%
			GAME	1	.2%
			JOB	1	.2%
			WEBSITE	1	.2%
			APP	1	.2%
			POOR PAY	1	.2%

8.2 Change of Opinion

In the post-survey, 174 students (27%) expressed interest in learning more coding in the future and 471 (73%) students expressed a lack of such interest (See Tables 2 and 3). While more students responded on the pre-survey than on the post-survey (the same number of student responses were recorded in the pre- and post- surveys, but more students chose to skip the question on the post-test), a higher percentage of students expressed interest in continued learning after the activity. Only student responses that did not skip the question are presented. Using a chi-squared test, a p-value < .003 was calculated for the observed responses on the post-survey, suggesting that the activity had a statistically significant effect.

Table 2. Number of Student Positive and Negative Responses

	PRE	POST	TOTAL
YES	169	174	343
NO	540	471	1011
TOTAL	709	645	1354

Table 3. Percent of Student Positive and Negative Responses

	PRE	POST
YES	23.84%	26.98%
NO	76.16%	73.02%

Also, of interest were shifts in student explanations as seen in Table 4. While more students expressed interest in continued learning after the activity, the only explanations that increased in popularity were FUN, BUILD, INTERESTING, COOL, HARD, MONEY, and HELP. Fewer negative responses were given in the post-survey than the pre-survey, so the majority of explanations decreased slightly. However, several categories dropped more than expected with fewer students claiming they were NOT GOOD at coding. Additionally, several responses were more common than before with a larger number of students claiming coding was NOT FUN, they were not interested in a coding job (NOT JOB), it did not match their IDENTITY, or they do not like MATH.

Table 4. Number of Student Comments in Each Category in Pre- and Post-Survey

Why?			Why Not?		
Category	Pre-Survey	Post-Survey	Category	Pre-Survey	Post-Survey
FUN	44 (26%)	69 (40%)	ALTERNATIVE	108 (20%)	74 (16%)
JOB	32 (19%)	25 (14%)	NOT INTERESTING	93 (17%)	54 (11%)
GAME	22 (13%)	17 (10%)	HARD	70 (13%)	55 (12%)
YES	20 (12%)	19 (11%)	BORING	63 (12%)	58 (12%)
BUILD	14 (8%)	17 (10%)	NO	51 (9%)	15 (3%)
INTERESTING	11 (7%)	16 (9%)	COMPUTER	45 (8%)	20 (4%)

FUTURE	10 (6%)	6 (3%)	NOT FUN	31 (6%)	46 (10%)
USEFUL	9 (5%)	5 (3%)	NOT GOOD	26 (5%)	0 (0%)
LEARN	9 (5%)	8 (5%)	USELESS	25 (5%)	12 (3%)
ROBOT	4 (2%)	1 (.6%)	YES	20 (4%)	10 (2%)
SMART	4 (2%)	3 (2%)	TIME	20 (4%)	14 (3%)
MAYBE	3 (2%)	0 (0%)	NOT JOB	17 (3%)	33 (7%)
WEBSITE	3 (2%)	2 (1%)	MAYBE	16 (3%)	5 (1%)
LANGUAGE	3 (2%)	0 (0%)	ALREADY	12 (2%)	0 (0%)
COMPUTER	3 (2%)	3 (1%)	IDENTITY	10 (2%)	19 (4%)
COOL	3 (2%)	4 (2%)	FUN	9 (2%)	7 (1%)
ALREADY	3 (2%)	1 (.6%)	PAIN	6 (1%)	4 (1%)
APP	2 (1%)	0 (0%)	IDK	6 (1%)	6 (1%)
HARD	2 (1%)	4 (2%)	WRONG	5 (1%)	9 (2%)
MENTOR	2 (1%)	0 (0%)	NATURE	5 (1%)	0 (0%)
MONEY	1 (.6%)	3 (2%)	MATH	5 (1%)	7 (1%)
HELP	1 (.6%)	7 (4%)	USEFUL	2 (.4%)	3 (.6%)
GOOD	1 (.6%)	0 (0%)	INTERESTING	2 (.4%)	1 (.2%)
WRONG	1 (.6%)	1 (.6%)	NO EXPERIENCE	2 (.4%)	0 (0%)
IDENTITY	1 (.6%)	0 (0%)	NOT NEED	2 (.4%)	0 (0%)
			EASY	1 (.2%)	0 (0%)
			JOB	1 (.2%)	0 (0%)
			GAME	1 (.2%)	0 (0%)
			WEBSITE	1 (.2%)	0 (0%)
			APP	1 (.2%)	0 (0%)
			POOR PAY	1 (.2%)	1 (.2%)

9 DISCUSSION

Some of the student responses match generally held assumptions; many students were interested in the creative power of CS and the potential career opportunities, with jobs and building each being one of the top five responses. However, the intrinsic enjoyment or fun expresses by students was not considered as often. Additionally, no students referred to the collaborative nature of CS. While the activity's "fun" nature and lack of collaboration may explain these deviations from expectation in the post-survey, their presence and absence in the pre-survey suggests that some assumptions may not be entirely correct – at least among this group of students.

While considered less often, the reasons students were not interested in CS may also provide insight into ways to better support students. While some reasoning, like an alternate preference is expected and reasonable, some provided explanations also showed student misconceptions, like a lack of use and poor pay. These concerns could potentially be addressed to increase student interest and engagement.

Some explanations illustrated potential contradictions as more students expressed a lack of interest in learning because they were not interested in a job than students who were interested because of job prospects on the post-survey. This may suggest a value in deemphasizing the job potential in CS and D&T fields. The potential motivating power of collaborative work paired with the lack of student responses about collaboration, may point to the power of increasing collaboration to increase motivation or could suggest that collaboration is not as motivating as we believe.

Some of the shifts from the pre- survey to the post- survey raise questions about the accuracy of how potential careers are presented in the classroom. While an increase in students' beliefs that coding is fun was positive, it may also give students unreasonable expectations as video games are engaging but not representative of computer science generally, or a career in computer science specifically.

Overall, an analysis of students' reasoning for continued engagement in coding and CS learning provided additional insight into potential ways for attracting students to computer science. Activities like HoC have the power to influence students' motivation and thus it is important to consider how activities will influence motivation. As we better understand how motivation functions in CS, it is possible that these insights can be transferred to D&T classrooms due to the significant similarities in the courses.

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Influence of Pre-professional Organizations on TEE Students

Emily Yoshikawa-Ruesch, Utah State University, emily.ruesch@usu.edu
Joseph Furse, Utah State University, joseph.furse@usu.edu

ABSTRACT

Since the 1970's, there has been a notable decrease in the number of Technology and Engineering Education (TEE) teacher preparation programs, as well as TEE teacher preparation program graduates within the United States. Previous studies have investigated reasons that post-secondary students pursue a TEE degree. However, no research is currently available regarding factors influencing student retention in TEE teacher education programs as well as factors that influence whether TEE preservice teachers enter the education field. Using the expectancy-value theory, this study investigates the relationship of participation of communities of practice in a student's intention to graduate from the program and enter the teaching field following graduation. This is the first step to a cross-sectional study looking at the influence of exposure to and participation in the Technology and Engineering Educators Collegiate Association on TEE teacher preparation program students. Participation in TEECA was measured ordinally with varying levels of participation depending on a student's activity level in student chapter meetings, conference attendance, and event participation.

Keywords: TEE, Technology Education, Preservice Teachers, Teacher Preparation, Pre-Professional Organization

1. INTRODUCTION

Volk (2019) has expressed concern regarding a notable decrease in the number of Technology and Engineering Education (TEE) programs (formerly recognized as Industrial Arts and Vocational Education) across the United States as part of a decrease in the number of TEE educators. This trend has been tracked back to the 1970s when there were 203 undergraduate Industrial Arts and Vocational Education teacher preparation programs in the United States. During this time, there were over 6000 undergraduate degrees awarded, which declined to just over 160 awarded by TEE programs in 2017.

Concerns with these statistics have motivated continued research surrounding the current status of TEE teacher preparation programs in the United States, including recruitment and retention (Litowitz, 2014; Love & Love, 2022). Litowitz (2014) investigated the similarities and differences in the curricula required and offered between these pre-service TEE programs that pre-service teachers are enrolled in. Additionally, Love and Love (2022) found that face-to face interactions with members of the TEE community were the most influential factor in pre-service teachers choosing to pursue their TEE degree.

Given the importance of face-to-face interactions within the TEE community for prospective technology and engineering teachers, further investigation into student recruitment and retention for students involved in a pre-service teacher collegiate association could prove to be an important variable in TEE program success. The prominent pre-service TEE teacher program in the United States is the Technology and Engineering Education Collegiate Association (TEECA) affiliated with the International Technology and Engineering Educators Association (ITEEA). Participation in TEECA allows for students pursuing a future in TEE a chance to network while competing in skills and content-based challenges against students from other universities. Students are also afforded the opportunity to participate in leadership positions at both a chapter and national level. Affiliation with, and participation in TEECA can vary between TEE teacher preparation programs. Further investigation of possible benefits associated with pre-service teachers' involvement with TEECA could help serve current TEE programs in their recruitment and retention of future teachers to the field. However, no research currently exists regarding TEECA and its role in the retention of TEE students.

1.1. Purpose of the Study

This study is a first step in an investigation of the influence of participation in TEECA on students' intentions to teach and continue in their undergraduate degree. The purpose of this study was to identify the participation levels in TEECA and their intentions to complete their TEE teaching degree as well as pursue a career as a TEE educator after graduation from their teacher preparation program.

2. LITERATURE REVIEW

2.1. TEE Teacher Shortage

Teacher shortages in the education system in the United States have been a recurrent trend throughout the history of the United States (Hawley, 1986; Ingersoll, 2003). Reasons found for teachers leaving have ranged from job dissatisfaction, retirement, pursuing a new career, and personal reasons (Ingersoll, 2001). However, in addition to teacher attrition, the teacher shortage in Career and Technical Education (CTE) has come as a result of a lack of college graduates in teacher preparation programs (Boyd et al., 2006; Conneely & Hyslop, 2009; Ingersoll, 2001, 2002). This is particularly true for TEE which lies under the CTE umbrella (Moye, 2009; Volk, 1997).

ITEEA has reported a decrease in existing TEE teacher preparation programs, which dropped from 72 reported programs in 2007 to 43 programs as of 2015 (Love, 2016; Warner et al., 2007). Various studies have been conducted to look at the curricula and content offered within these programs (Litowitz, 2014; Strimel, 2013). In addition to these studies, Love (2016) investigated further into the informal experiences that were offered within the various TEE teacher preparation programs. This study looked at mentoring and organization or club experiences. Love and Love (2022) continued this research to find that face-to-face interactions with secondary TEE educators, alumni, and faculty were a significant influencer for students pursuing a TEE undergraduate degree. While these studies help to show secondary influences that have led to the recruitment of students enrolling in TEE teacher preparation programs, there remains an absence of studies surrounding collegiate experiences that encourage the retention of preservice teachers within TEE or the increased intentions of preservice teachers to enter the teaching profession.

2.2. TEE Programs and TEECA Participation

In addition to the different curricula required for graduation for each TEE teacher preparation program, many TEE programs do not require students to pursue a teaching license, but offer it as an optional track. These programs offer a degree for students to go into industry pursuing manufacturing, instructional design, graphic design, engineering technology, etc. Despite these differences between TEE teacher preparation programs, an opportunity that is afforded to all TEE programs is affiliation with the Technology and Engineering Education Collegiate Association (TEECA). Whether or not a student's school is registered as a TEECA chapter, students can register with a student membership for ITEEA, which would automatically enroll them in TEECA. Both chapters and students can vary in their degree of involvement from no involvement to affiliation, conference attendance, and participation in competitive events. These competitive events include problem solving, manufacturing, communication and design, robotics, and teaching. In addition to the competitive events, university students are afforded an opportunity to network as well as explore various paths for future employment and education when attending conferences.

Universities participating in TEECA have brought a wide range of number of students. The national TEECA event in April 2023 was attended by eight universities. These universities ranged in bringing anywhere between three to thirty students. There is no maximum capacity that a university is allowed to bring, but they may be limited by funds or student interest.

2.3. Theoretical Framework

Within the expectancy-value framework, Watt and Richardson (2007) worked to explore Factors Influencing Teaching Choice (FIT-Choice). This study originally took place in Australia looking at the motivating factors for individuals to work within the teaching profession. By narrowing the expectancy-value theory to look specifically at experiences and motivations that teachers experience, the FIT-Choice scale was created. Additional studies found that a key motivator for pre-service teachers in the United States pursuing a teaching career were centered around socialization influences and social utility (Richardson et al., 2014).

These studies have helped to inform research on why individuals pursue a career in education. However, further studies may help to investigate whether the same factors help to retain preservice teachers throughout their training experience. Further research will help develop understanding of and improve retention and motivation for preservice teachers preparing to enter the field of education.

2.4. Preservice Teacher Preparation and Retention

Once an individual begins to pursue a career in education, it has been found that perceived field experiences are a key influence in the preservice teachers' career preparation (Erdem & Demirel, 2007; Guyton & McIntyre, 1990; Hollins & Guzman, 2005). These field experiences include activities that involve learning by doing (Cruickshank & Armaline, 1986).

In the creation of personal identity, preservice teachers often connect with the positive field experiences they have when in the field (Dassa & Derose, 2017). Teachers that reported feeling positive during field experiences felt they would succeed in creating positive teaching environments for their future students (Beltman, 2015). Rogoff (1991) explained that to become a skilled practitioner within one's community, the learner should participate in various and repeated experiences. This experience should include both routine experiences and challenging situations. Pre-professional organizations may help provide the experience and skills needed to feel confident in pursuing school positions post-graduation (Cobb, et al., 2015).

3. METHODS

3.1. Research Design, Population, and Sampling

This study utilized a cross-sectional design looking at current students enrolled in TEE programs currently affiliated with TEECA from across the nation. This study did not differentiate between programs that lead all enrolled students to receiving a teaching license and programs that offer it as an optional track for the program. The study relied on voluntary response sampling through an online survey.

The researcher disseminated a survey that included an adapted FIT-Choice Scale through current faculty of TEE teacher preparation programs to students currently enrolled in their programs. The competitive events coordinator was contacted to access the contact information for programs affiliated with TEECA over the past five years. The faculty and advisors of these programs were contacted and asked to forward the email inviting preservice teachers to participate in the survey.

3.2. Data Collection and Analysis

The survey collected information on students' level of participation in TEECA. Participation included being a registered member, attending chapter meetings, attending conferences, and participating in events. In addition to TEECA participation, TEE students were asked to rate their intent to pursue a career in teaching as well as continue in their undergraduate program, both of which were measured on a 5-point Likert scale.

In addition to student attitudes, demographic information was collected including gender, year in school, and year in major. The survey data was analysed using descriptive statistics.

4. RESULTS

4.1. Sample Description

It is unknown how many TEECA advisors and program faculty forwarded the invitation to participate in the study to their TEE students. From the programs that did send on the survey, the survey was started by 65 participants. However, only 41 participants completed all items on the survey. From the survey, 47 of the participants provided their gender. It was found that the majority of respondents were female (see Table 1).

Table 1.
Gender demographics of survey participants

Gender	*f*	%
Male	21	44.7
Female	24	51.1
Non-Binary or Third Gender	2	4.3

Students also showed a wide range of years that they have been attending college. However, most students are within their first three years in the TEE undergraduate major (see Table 2).

Table 2.
Total number of years in college and number of years in the major that the student was currently completing

Current year in post-secondary education	*f*	%
1st Year	7	14.9
2nd Year	14	29.8
3rd Year	13	27.7
4th Year	6	12.8
5th Year	5	10.6
6th Year	1	2.1
10+ Years	1	2.1
Year currently being completed as a TEE major		
1st Year	16	34.0
2nd Year	12	25.5
3rd Year	13	27.7
4th Year	6	12.8

4.2. TEECA Participation

For TEECA participation, there was a wide range of years and levels of participation (see. Table 3). There were 42 participants that completed the four items regarding TEECA participation. With the individual variables of years of membership, number of conferences attended, number of competitions participated in, and how often they attended chapter meetings, most participants showed little to no experience and low levels of participation.

Table 3.
TEECA Participation Variables

Number of years registered as a TEECA member	***f***	**%**
0	18	42.9
1	10	23.8
2	8	19.0
3	5	11.9
4	1	2.4
Number of conferences attended		
0	19	45.2
1	13	31.0
2	4	9.5
3	4	9.5
4	2	4.8
Number of competitions participated in		
0	20	47.6
1	11	26.2
2	5	11.9
3	1	2.4
4	2	4.8
5	1	2.4
6	2	4.8
How often student attended TEECA chapter meetings		
Never	20	47.6
Once per semester	4	9.5
Monthly	11	26.2

Weekly	7	16.7

For a summarized look at the participation in TEECA, participant responses were put into an ordinal scale. For each activity that a student had participated in, they were given one "point". If participants did not have any level of participation, they would be assigned as a level 0 for participation. If students had participated in two of the activities (for example, attended conferences and competed in competitions but had not registered as a TEECA member or attended TEECA chapter meetings), they were assigned to a level 2. From this ordinal ranking, it was found that the majority of participants had either a high level of participation (level 4) or no participation (level 0; see Table 4).

Table 4.
Ordered TEECA Participation Levels

Ordinal Participation Level	*f*	%
0	16	38.1
1	2	4.8
2	3	7.1
3	1	2.4
4	20	47.6

4.3. Student Intentions

Participants were asked to rank their interest in teaching as well as their intentions to graduate from their major using a 5-point Likert scale. The students that participated in the study showed a high interest in teaching as well as high intentions to complete the major (see Table 5). It can be noted that there was one student that participated in the survey that indicated that they have interest in teaching, but did not plan on graduating from their TEE program.

Table 5.
Students interest in teaching after graduation and students' interest in graduating from their TEE program (n = 43)

	M	SD
Interested in teaching after graduation	4.63	0.85
Intentions to graduate within the TEE major	4.72	0.70

5. DISCUSSION

5.1. Sample Demographics

Of those that elected to participate in the survey, the majority of the participants were female. As females are not the majority of TEE students (Lester, 2010; Sanders, 2001), this data may not be representative of the population of TEE students as a whole. The current sample shows high intentions to pursue teaching as a career across all levels of participation in TEECA. However, the current sample size does not permit further analysis of relationships between student participation and student intentions that would lead to a reliable conclusion. To address this, the survey will be sent out to the programs an additional time in an effort to reach a sample size sufficient enough to appropriately evaluate the relationship between students' participation in pre-professional organizations and their intentions to continue in their program and pursue teaching as a career.

At this point, none of the participants in this study were completing more than 4 years in their program. As some of the participants may have transferred from another degree, the number of years in the program does not indicate how close to completion in their program the student is. For example, a student could have transferred from another degree program and is in their second year in the TEE program, but this could also be their fourth year of university studies. It may be informative in the future to look into how many years the students may have left in addition to how many years the student has already been enrolled in post-secondary education and their specific program.

Additionally, there are several TEE programs in the United States that are not solely education programs. Some programs are general Technology and Engineering Studies degrees that provide an option for certification or licensure in education, but it is not required for the degree. The interest shown towards teaching may indicate that the survey was mostly participated in by students pursuing the education route.

5.2. Participation Levels

Nearly half of the participants reported no participation in TEECA. While face-to-face interactions have been shown to be influential in students' choice to pursue TEE as a career, students may be limited with additional interactions as there are low number of students participating in conferences.

This also shows that TEECA is not being fully utilized as a resource to prepare students for a future in TEE. While programs differ in emphases and courses offered, TEECA is a national opportunity for students to make connections and find resources from across the country. Instead of looking toward opportunities offered by ITEEA and TEECA, it is possible that programs have more of an emphasis in other professional organizations such as the Association for Career and Technical Education (ACTE). However, ACTE does not have a pre-professional organization used to focus on pre-service teachers looking to teach CTE content in the future. They also do not have specific events or opportunities afforded to undergraduate students specifically.

5.3. Next Steps

After looking at the participation and the interest in continuing in their teacher education program and interest in teaching as a career, further analyses will help to investigate relationships between participation in TEECA and the value given to the career and interest in continuing in their undergraduate degree. Given the belief values explained in the FIT-Choice scale, continued investigation and analysis may help to inform further on the belief values (i.e., the utility of TEE, the individual's ability to teach the content, and the individual's expectation to perform well in the content area) that may or may not be increased through participation in TEECA for future TEE teachers. Additional interviews will be conducted and analysed to understand the influence of TEECA in student's intent to teach and continue in their TEE teacher preparation programs. The current sample size prevents the ability to claim any causation, but continued survey dissemination may help to support these analyses.

Further studies may help to inform what interactions lead to students' intentions to become a teacher or pursue a career in education. It is unclear if face-to-face interactions during post-secondary education are as influential as the influences experienced prior to post-secondary education. Additionally, as many undergraduate TEE programs differ in content, exposure to field experiences, TEECA affiliation, emphasis on teacher-licensing, etc., additional investigations may help to inform the TEE community on the effectiveness of current practices used for recruitment and retention. What have programs done to help build their program and for those that are programs that are industry focused but have a teaching track, how many students enrolled are going into education?

Understanding and knowing what current recruitment and retention strategies are being offered by various programs may help to build up programs that are struggling with recruitment or enrolment numbers. This information may also help to know how to best serve undergraduate students and understand what these future teachers may need for professional development and how professional organizations can best serve these educators.

Additionally, as ITEEA is seeking to bring the next generation of technology and engineering educators into the national community, there seems to be a gap in reaching out to teachers in pre-service programs. Additional investigations could help inform how to best reach out and include and best serve pre-service teachers leading to increased participation once they are practicing educators.

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Impact of a Creative Design Course on Undergraduates' Creative Confidence

Melissa Zrada, The College of New Jersey, bradle23@tcnj.edu

ABSTRACT

This study was conducted as part of an effort to critically analyse and assess student outcomes in Creative Design, an undergraduate course at [Institution]. Topics covered in the course include, but are not limited to: the design process, technical drawing, working with tools and materials, modelling a product or design, and design elements and principles. While some students (e.g. Technology and Engineering Education majors) are required to take this course, it is also open to students in all majors, and is a Literary, Visual, and Performing Arts liberal learning course option. There are typically several sections of the course offered each semester, and it is taught by a variety of instructors. The research aimed to investigate how Creative Design impacted undergraduate students' creative thinking, creative self-efficacy, and spatial thinking skills. Students were asked to complete instruments to assess each of these areas, both at the beginning and end of a semester in which they were enrolled in the course. Students also completed a demographics survey, which allowed outcomes to be explored further, for example, by major (STEM/non-STEM). The focus of this manuscript is creative self-efficacy, measured by the Short Scale of Creative Self (Karwowski, 2011). Results indicate that Creative Design may raise female students' creative confidence, resulting in female students feeling nearly as creatively confident as male students by the culmination of the course. While the results of this study are specific to Creative Design, further research could explore the effects of other design, creativity, and technology courses on undergraduate student outcomes.

Keywords: Creativity, Creative confidence, Creative design, Undergraduate education

1. INTRODUCTION

Creative Design is an undergraduate level course offered at the author's institution. It is housed in the School of Engineering within the Department of Integrative STEM Education. The course is a requirement for some majors on campus, including Technology and Engineering Education.

However, it is also a liberal learning course that fulfils a Literary, Visual, and Performing Arts requirement. Thus, students from programs all across campus enrol in Creative Design. The course description is as follows:

> This is a foundational course that looks at the elements and principles of design as related to practical products, systems, and environments. It introduces students to the creative process practiced by artists, designers, and engineers, valuable to them as both future producers and consumers. Content includes thinking, drawing, and modeling skills commonly used by designers; development of a design vocabulary; the nature and evolution of technological design; the impacts of design on the individual, society, and the environment; patents and intellectual property; human factors; team design; and appropriate technology, risk analysis, and futuring techniques. Design problems are presented within real-world contexts, using field trips and outside speakers. Students complete a major design project, document their work through a design portfolio, and present their solutions before the class. Weekly critiques of class projects build fluency, confidence, and creativity. ([Institution], n.d.)

The goal of this research is to explore how Creative Design impacts undergraduate students' creative thinking, creative self-efficacy, and spatial thinking skills. This manuscript will focus on creative self-efficacy, which was measured using the Short Scale of Creative Self (Karwowski, 2011).

2. LITERATURE REVIEW

This study builds on previous research from Huffman and Figueroa (2017) and Huffman and [Author] (2021) on the Creative Design course at [institution]. Prior work has investigated design thinking and creativity (Huffman & Figueroa, 2017) as well as creative pedagogy employed by Creative Design instructors (Huffman & [Author], 2021).

Recent studies have explored aspects of undergraduate creativity (Daly et al., 2014; Miller & Dumford, 2016; Snyder et al., 2019), specifically creative confidence (Mathisen & Bronnick, 2009; Payne & Whitworth, 2021; Pretz & McCollum, 2014; Rauth et al., 2010; Stolz et al., 2022; Vally et al., 2019). There is evidence that various types of learning experiences can positively impact creative confidence. Mathisen and Bronnick (2009) demonstrated that participation in a five-day creativity training course significantly improved undergraduate students' creative self-efficacy. Vally and colleagues (2019) investigated a university-level "creativity and innovation course" (p. 72), which resulted in a significant improvement in students' creative self-efficacy. Payne and Whitworth (2021) explored creative confidence in an undergraduate biochemistry course. They found that students who were challenged to design experimental protocols during a laboratory exercise experienced improved creative self-efficacy (Payne & Whitworth, 2021). Each of these examples illustrates ways in which various educational experiences can impact creative confidence.

There is evidence that creative self-efficacy is directly related to other factors that are important to learning. Alvarez-Huerta and colleagues (2022) found that creative self-concept and critical thinking disposition were positively correlated. Alvarez-Huerta and colleagues (2021) also found creative self-concept and student engagement to be positively correlated. Further, they explored predictors for creative self-concept, and determined all of the following to be predictors: “collaborative learning, student-faculty interaction, higher-order learning, reflective and integrative learning, and high-impact practices” (Alvarez-Huerta et al., 2021, p. 7). Both of these studies highlight the importance of understanding creative confidence, how it can be fostered in education, and its impacts on learning.

Creative self-efficacy has also been studied with respect to gender. As stated above, Alvarez-Huerta and colleagues (2021) investigated creative self-concept as it related to a number of student engagement factors. The results of this study indicated that male students had a higher creative self-concept than female students, both during their first and fourth year of schooling. However, both male and female creative self-concept scores improved from year one to year four (Alvarez-Huerta et al., 2021). Kijima and Sun (2021) researched the creative confidence of female middle school students, and reported that these students experienced improved creative confidence after a three-day design thinking intervention.

The research presented in this manuscript fits into the broader research scope on creativity in undergraduate education. It explores the impact of a creative design course on undergraduate students’ creative self-efficacy, with particular attention to major (STEM/non-STEM) and gender. Applications for this work include design and technology education, but also undergraduate education broadly.

3. METHODOLOGY

3.1. Participants

All study participants were enrolled in Creative Design at [institution] during the Fall 2021 semester. Participants were enrolled in one of three sections of the course, which were taught by two different instructors. Both instructors included the study measures in their course(s) as homework assignments. Students were able to indicate on the Informed Consent form whether or not they agreed to have their data used for research purposes.

After verifying both beginning and end of semester agreements and matching anonymous identifiers, the final sample included 32 students. Each of [institution]’s seven schools were represented by this sample: Arts and Communication, Business, Education, Engineering, Humanities and Social Sciences, Nursing and Health Sciences, and Science. End-of-semester demographics responses indicated that 18 students identified as male and 11 students identified as female. The remaining students either did not complete this item or selected “Prefer not to say” for this item.

3.2. Methodological tools

Participants completed four assessments within this study, both at the beginning and end of the semester, listed here in order of completion: Short Scale of Creative Self (Karwowski, 2011), Guilford's Alternate Uses Task (Guilford et al., 1978), Purdue Spatial Visualization Test: Rotations (Guay, 1976), and a demographics survey. The demographics survey asked students to provide the following information: Gender, Year, Major(s), Minor(s), Course section, All other courses you are taking this semester.

This manuscript will focus on student responses to the Short Scale of Creative Self (Karwowski, 2011), which is an eleven item survey. Respondents self-assess beliefs about their own creativity, ranking each item on a Likert scale from 1 (Definitely not) to 5 (Definitely yes). Responses to the eleven items are averaged to generate a Creative Self-Concept Scale (Karwowski, 2011). Statistical analyses were performed using IBM SPSS Statistics.

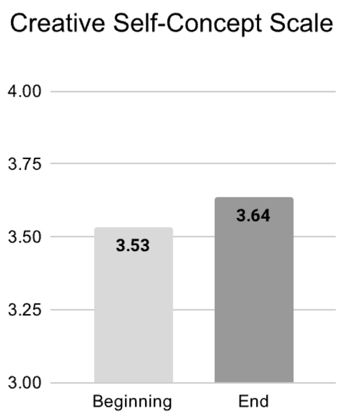
3.3. Implementation

All participants completed an online Informed Consent form that had been approved by [institution] Institutional Review Board. As stated in section 3.1, students were required to indicate how their data could be utilised: "It is okay to use my anonymous data for research purposes" (Yes/No). Each study instrument was completed virtually via a Qualtrics survey. Students were asked to complete the instruments in one sitting, without the assistance of any outside resources. Students participated both at the beginning and end of the semester in which they were enrolled in Creative Design.

4. RESULTS

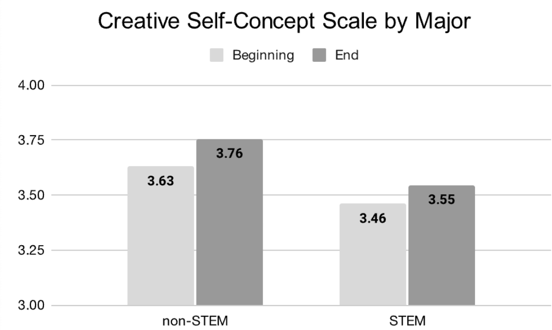
As measured by the Short Scale of Creative Self (Karwowski, 2011), creative confidence did not change significantly from the beginning (M = 3.53, SD = 0.646) to the end of the semester (M = 3.64, SD = 0.676), t(29) = –1.032, p = 0.311 (Figure 1).

Figure 1. Creative Self-Concept Scale results for all participants at the beginning and end of a semester in which they were enrolled in Creative Design.



The differences between non-STEM and STEM majors were investigated at both the beginning and end of the semester (Figure 2). The acronym STEM stands for Science, Technology, Engineering, or Mathematics. 13 students were categorised as STEM majors and 17 students were categorised as non-STEM majors. Non-STEM majors did not experience a significant change in creative confidence from the beginning of the semester (M = 3.63, SD = 0.689) to the end of the semester (M = 3.76, SD = 0.704), t(12) = –1.173, p = 0.263. Similarly, STEM majors did not experience a significant change in creative confidence from the beginning of the semester (M = 3.46, SD = 0.621) to the end of the semester (M = 3.55, SD = 0.661), t(16) = –0.540, p = 0.596. Further, there was no significant difference in creative confidence between non-STEM and STEM majors at the beginning of the semester (t(28) = 0.706, p = 0.486) or at the end of the semester (t(28) = 0.834, p = 0.411).

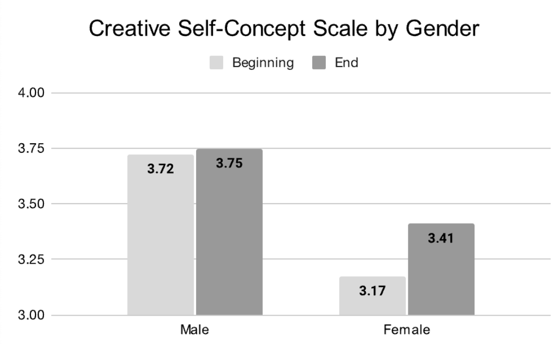
Figure 2. Creative Self-Concept Scale results, presented by major type, at the beginning and end of a semester in which participants were enrolled in Creative Design.



The differences between male and female students were investigated at both the beginning and end of the semester (Figure 3). 18 students identified as male and 11 students identified as female. Male students did not experience a significant change in creative confidence from the beginning of the semester (M = 3.72, SD = 0.416) to the end of the semester (M = 3.75, SD = 0.586), t(17) = –0.195, p = 0.848. Similarly, female students did not experience a significant change in creative confidence from the beginning of the semester (M = 3.17, SD = 0.822) to the end of the semester (M = 3.41, SD = 0.795), t(10) = –1.429, p = 0.184.

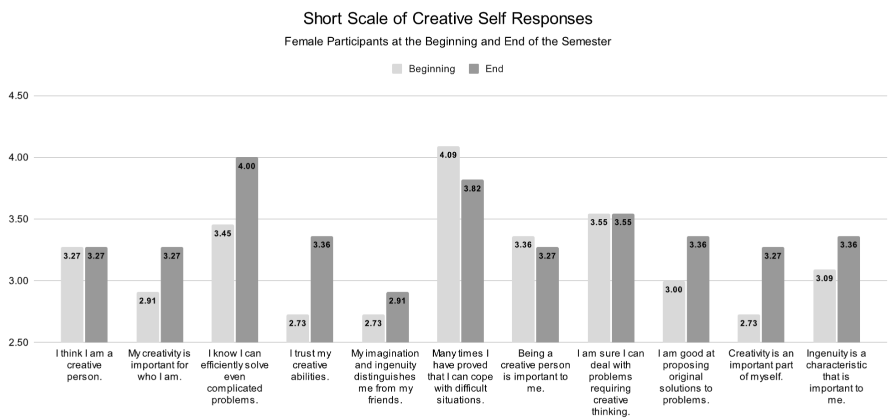
A further comparison was conducted to investigate differences between male and female creative confidence both at the beginning of the semester and at the end of the semester (Figure 3). The difference between male and female creative confidence at the beginning of the semester was nearly significant (t(13.187) = 2.054, p = 0.060); equal variances not assumed (F = 6.396, p = 0.018). However, the difference between male and female creative confidence at the end of the semester was clearly not significant (t(16.673) = 1.240, p = 0.232); equal variances not assumed (F = 5.149, p = 0.031).

Figure 3. Creative Self-Concept Scale results, presented by gender, at the beginning and end of a semester in which participants were enrolled in Creative Design.



Further analyses explored female participants' responses on each item of the Short Scale of Creative Self (Karwowski, 2011) (Figure 4). There was a nearly significant difference on two of the survey items from the beginning of the semester to the end of the semester: Item 3 ("I know I can efficiently solve even complicated problems.") and Item 10 ("Creativity is an important part of myself.") (Karwowski, 2011). Female students rated their confidence in solving complicated problems (Item 3) lower at the beginning of the semester (M = 3.45, SD = 1.293) than at the end of the semester (M = 4.00, SD = 0.894), t(10) = –2.206, p = 0.052. Female students also rated the importance of creativity (Item 10) lower at the beginning of the semester (M = 2.73, SD = 1.191) than at the end of the semester (M = 3.27, SD = 1.191), t(10) = –2.206, p = 0.052.

Figure 4. Creative Self-Concept Scale results by item for all female participants.



5. DISCUSSION

The data analyses indicate that enrolment in Creative Design did not significantly improve students' creative confidence over the course of the semester. This finding held true when looking across majors: both non-STEM and STEM majors did not experience a significant change in creative confidence. This finding also held true when looking at gender: both male and female students did not experience a significant change in creative confidence. However, it is interesting to note that at the beginning of the semester, male students were more confident than female students at a probability that is approaching significance. By the end of the semester, there was clearly no significant difference between female students' and male students' creative confidence.

Exploring responses to specific items on the Short Scale of Creative Self (Karwowski, 2011) may provide additional insight into what aspects of one's creative confidence were improved by participating in a Creative Design course. Female students experienced a nearly significant increase on two survey items: "I know I can efficiently solve even complicated problems." and "Creativity is an important part of myself." (Karwowski, 2011).

5.1. Limitations

While these findings are not wholly aligned with those of previous studies discussed in the Literature Review section, one must acknowledge several limitations that may have impacted the results. Despite recruiting from three different sections of Creative Design, the number of students who participated was ultimately quite low. It would be ideal to have a much larger sample of students. On a similar note, multiple sections of the course result in various course instructors and experiences. While all Creative Design professors adhere to the same general content, there are certainly differences in assessments and teaching styles.

5.2. Future directions

Future iterations of this study would ideally focus on the Short Scale of Creative Self (Karwowski, 2011); it may have been too overwhelming to ask students to complete four instruments in one sitting. The plan moving forward is to collect data from more Creative Design sections, perhaps across multiple semesters/years. This should provide an ample amount of participants.

Additionally, delving into more qualitative data may provide additional insight on what specific experiences are most valuable in boosting creative confidence. This data could include, but is not limited to, reflections, interviews, and course artefacts.

Finally, this research was specific to one course, but could be expanded upon to explore how other design and technology courses might impact creative self-efficacy, or how creative self-efficacy changes over the course of one's undergraduate career.

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Academic Posters

POSTER 1: Using the Mirror as a Working Tool in Handicraft Education

Minna Arvidsson, Karlstad University, minnaarvidsson@kau.se
Nina Kilbrink, Karlstad University, nina.kilbrink@kau.se
Stig-Börje Asplund, Karlstad University, stig-borje.asplund@kau.se

In interaction between students and vocational teachers, technical artefacts constitute an essential part for the development of vocational students' future professional knowledge. Although vocational learning has been an under-researched area, there has been an increased interest within the vocational education research to examine the teaching and learning processes that take place when vocational students and teachers interact in vocational school settings. The presence of physical objects such as tools, machines and material in the teaching and learning processes within vocational education, which encompass a central aspect of a vocational subjects' specific characteristics, is a dimension which is often overlooked. In the Handicraft programme (specialization hair- and makeup stylist) at Swedish upper secondary vocational education, a large part of the practical work that students are engaged in is to view their work through the mirror. Therefore, the focus in this study is what learning content is made relevant when teacher and student(s) are interacting in front of the mirror. The data for the study consists of video recorded lessons from the Handicraft Programme, and the study is based on CAVTA (Conversation Analysis and Variation Theory). Based on CAVTA, the process of learning includes what is being learned and how learning is done in interaction between the teacher and student(s) in the authentic and enacted teaching session. At the conference, we will present results from detailed analysis of sequences when the teacher and the students interact in front of the mirror and what vocational knowledge is made possible to learn in these interactions.

POSTER 2: Bygg Och Konstruktion as Technology in the Swedish Preschool

Björn Citrohn, Linnéuniversitetet, bjorn.citrohn@lnu.se
Johan Boström, Linnéuniversitetet, johan.bostrom@lnu.se

Construction with different materials, tools and techniques has a long history as an activity in preschool. In Sweden, this area of activity has commonly been known as bygg och konstruktion (to build and construct). However, exactly what this term entails in relation to technology as a content matter is not entirely clear. But since the construction activities has such a rich history in preschool, official documents and guidelines could shed light on this. Consequently, the aim of this paper was to examine construction activities' role in preschool activities and how these activities has been presented historically. This was done by examining historical documents pertaining to the Swedish preschool. The examination shows that bygg och konstruktion has been a distinct part of different content matters in official governmental reports and curricula documents since at least the early 1950s, during the same time period when the Swedish National Board of Health and Welfare became responsible for the Swedish child care. In the 1970s and early 1980s, during a period when the political discourse revolved around how a perceived lack of interest in natural science from the populace could hinder economic growth, it was partly placed in the content area of natural science. During the end of the 1980s and early 1990s, during the same time as the school subject of technology emerged, it was partly placed in the new content area of technology. During all of this time, parallel to its inclusion in natural science and technology, bygg och konstruktion can also be found in the aesthetical content area. The analysis of the historical documents also shows that no clear distinction is made between bygg and konstruktion –– the terms are used as synonymous to each other.

POSTER 3: Teaching K-8 Children about the Internet Will Be Difficult: Preliminary Findings from a Mixed-Method Study

Cyril Brom, Charles University, brom@ksvi.mff.cuni.cz
Anna Yaghobová, Charles University, yaghobova@ksvi.mff.cuni.cz.
Anna Drobná, Charles University, drobna@ksvi.mff.cuni.cz
Marek Urban, Czech Academy of Sciences, marek.m.urban@gmail.com

In the contemporary society, children need to become competent internet users. Previous studies suggested that in order to achieve this goal, it helps if children understand basics of how internet works. However, these studies also indicated that children's knowledge about internet's functioning is patchy. Furthermore, children possess many misconceptions and existing research does not examine how to boost their understanding of the internet's functioning. Here, we present a mixed-method study, in which children (Grade 4, 6, 8; N = 50 + 50 + 38): a) were interviewed about how the internet works; b) half of them (random assignment) was explained this topic during a 50-min-long 1:1 tutoring session (with activating tasks); c) were interviewed again four months later. The interviews and the teaching session examined/promoted understanding of the following concepts: servers, wifi routers, network routers, wireless vs. wire connection, storage of data on the internet, digital traces, and cookies; among others. The interviews are now being analysed through thematic and frequency analyses. Preliminary findings corroborate previous findings about misconceptions and are consistent with 'knowledge in pieces' theories of knowledge representations. Typical reasoning among children about the internet structure includes satellites and central computers/towers. Only expert children know about distributed, server-like storage. Children understand the internet primarily through their personal experiences, only most knowledgeable children view it as a global network with a complex internal, but only vaguely understood, structure. The teaching session promoted understanding in short term, but much less so in a long term. Four months later, only few children retained knowledge about network routers, some about servers. Children tended to return to their prior misconceptions and their post-understanding remained patchy. Some held both prior misconceptions and contradictory new ideas. Altogether, our results suggest that teaching K-8 children about the internet functioning will be challenging and specific approaches, such as those capitalizing on activating children's prior knowledge, will be required.

POSTER 4: Developing a Teaching Chatbot for Learning Tools and Equipment in Technology Classrooms

Yu-Fan Cheng, National Kaohsiung Normal University, ok5629669@gmail.com
Szu-Chun, Fan, National Kaohsiung Normal University, scfan@mail.nknu.edu.tw

Using and applying tools and equipment for designing and building projects has always been indispensable in living technology classrooms. However, students must be aware of their proper use to avoid mistakes and safety concerns. In recent years, chatbots have been widely used in various fields, offering instant, interactive responses, and their application in educational contexts has also increased rapidly. Therefore, this study developed a chatbot for LINE, a popular messaging app in Asia, for teaching standard hand tools and equipment in living technology classrooms at secondary schools. This chatbot covered (1) measuring tools, (2) hand tools, (3) power tools and equipment, and others. A total of 49 tools and pieces of equipment were included. The instructional content for each consisted of (1) instructions, (2) operating procedures and skills, and (3) troubleshooting and maintenance. The user interface adopted point-and-click forms and graphical menus to quickly guide users searching for specific information. In addition, users can enter relevant keywords and the chatbot will answer the corresponding content. The chatbot is expected to solve student questions more efficiently and assist teachers, improving the effectiveness and convenience of these hands-on lessons.

POSTER 5: An Autoethnographic Reflection on New Educational Technologies in the Design and Technology Curricula from Schools in Dubai and England

Sarah Finnigan, Liverpool John Moores University, s.finnigan@ljmu.ac.uk

To what extent does design and technology (D&T) equip children and young people with the technological skills they need for the future? This reflection discusses and critiques observations on international D&T curricula in the United Arab Emirates and the United Kingdom, exploring innovative practices such as virtual reality (VR) and other new educational technologies to support assessment and add depth to the curriculum. In this paper, I discuss educational perspectives from an autoethnographic standpoint and the extent to which contributing factors, such as culture, have impacted me as a D&T practitioner. My observations come from teaching and leading within a an oversubscribed and high-performing co-education international through-school in Dubai. From five years situated within this particular environment I participated in the teaching and learning of the subject across the primary and secondary phases, in an expatriate community of over two thousand students from over eighty different nationalities. In comparison to the second educational environment, being an oversubscribed state co-educational secondary school in the Greater Merseyside area in England. These two educational establishments have distinctly different demographics and methods of delivery in their approach to D&T. My reflections on some of the challenges and 'quick wins' are shared with the aim to offer insights and observations that any

POSTER 6: Five Years Construction Kits in Primary Schools: Results and Impacts of a Project to Facilitate Technology Education: an Evaluation Study

Martin Fislake, University of Koblenz, fislake@uni-koblenz.de
Jana Schumacher, University of Koblenz, jschumacher@uni-koblenz.de

In March 2018, metal construction kits were distributed to all elementary and special schools in Rhineland-Palatinate. They were distributed to all elementary and special schools in Rhineland-Palatinate as part of the MINT project "Technikkiste" (transl.: technology box). At the end of the year 2018, three more expansion sets with solar cells followed for each school. So far, no request has been made to the schools, even after five years of the project's start made to the schools as to how and whether they use this material. Therefore, within the scope of this research an evaluation study for the elementary schools in the form of a questionnaire was carried out in July 2023. The study is intended to find out both the current usage behavior with the metal construction boxes as well as to get an impression of the teachers regarding the in-service training measures that took place as part of the project. 921 elementary schools in Rhineland-Palatinate were invited to participate in the online survey. 69 answered the questionnaire some more gave informal feedback. The special schools, which were also supposed to have received the metal construction kits, were left out of the survey, as they are likely to have different usage patterns and therefore a different behavior and would therefore require a different questionnaire. It is particularly noteworthy that only about 70% of the participants who responded are even aware of the metal construction boxes. Around 30% stated that they were not familiar with the metal construction kits. In addition, only about 43% of the participants indicated that the metal building boxes have ever been used in the classroom at their school. One of the main reasons that participating teachers do not use the metal building boxes is that the school has not received boxes or has too few for classroom use. This brief excerpt from the survey results already shows that the MINT promotion project is not showing the success that the Ministry of Education had hoped for.

POSTER 7: Effects of Technology Education Classes: Meta-analysis on Research Findings in the Republic of Korea

Hyuksoo Kwon, Kongju National University, hskwon@kongju.ac.kr
Yubin Lee, Jusan Middle School, youbin8014@naver.com

In South Korea, Technology education is one of the national curriculum compulsory subjects, and despite the importance and value, public awareness toward technology and technology education is very low. Whenever the curriculum is revised, the value and place of technology education have been challenged. The purpose of this study is to analyse effects on students of technology education classes. Meta-analysis is conducted to calculate the effect size of technology education classes in the Republic of Korea. Data are collected through an integrated searching engine of Korean academic database. From 2000 to 2022, 61 studies are analysed by Comprehensive Meta Analysis 4.0. The result shows an intermediate effect size in technology education classes. A total of 148 effect sizes are analysed by dividing the subcategories into publishing type, teaching method, school level, experimental type, and dependent variable. For the publishing type, academic journals and thesis papers show the intermediate effect size. Particularly, studies for elementary school level indicate a high effect size, followed by middle school and high school. The dependent variables show intermediate effect sizes of the order of affective variables (e.g., attitude, motivation), psychomotor variable, and cognitive variables (e.g., academic achievement). Based on the findings, this study can make the following recommendations. More studies for proving the value and importance of technology education classes should be conducted.

POSTER 8: Development of System Modules for Children's Games with Vision and Music-Based Interactive Real-Time Feedback Modules: A Design-Based Research Approach

Fang-Yu Liu, Chang Gung University of Science and Technology, fyliu@mail.cgust.edu.tw
Siyi Tzeng, Shih Hsin University, syyit@mail.shu.edu.tw

Most past research on young children's attention focused on the design of multimedia games based on visual stimulation. In contrast, few studies have been on the development of teaching tools focusing on auditory stimulation. This study aims to develop a real-time interactive digital game with music and eye tracking for young children. The Design-Based Research (DBR) approach was adopted. Melodic tunes and lyrics composed by the researcher constitute the auditory stimulation, paired with visual images, in a game emphasizing interactivity between game content and players. Discussions were held between the various members of the developing team, during which the game developers and domain experts proposed suggestions to the researcher, who then continuously fine-tuned the game in line with the research objective. Our preliminary findings suggested that DBR, which emphasizes child-centered design, provides a novel and innovative approach to digital game design.

POSTER 9: Effective Professional Development to Enhance the Teaching of Design and Technology: an On-going Small-scale Research Study

Janine Pavlis, St Mary's University, janine.pavlis@stmarys.ac.uk

High-quality Design and Technology (D&T) education is essential for pupils in primary schools. Professional development (PD) is a crucial tool that offers primary school teachers the ability to maintain high-quality teaching in order to improve pupil outcomes. The National Curriculum in England and Wales requires children in KS1 and KS2 to be hands-on and creative through the designing and making of products within their D&T learning. Currently, a local authority (LA) in an outer London borough, works with teacher facilitators to run PD virtual networks. Teachers who coordinate and lead on specific subjects within a school are invited by the LA; however, through summative feedback, conversations around designing, delivering and assessing D&T have been viewed as challenging when undertaking PD networks online. Initial research has shown that teachers within the borough lack confidence and feel their skills and knowledge required to teach D&T effectively are limited. This paper reports on research-led guidance reports to support the designing and evaluating of effective PD. This ongoing mixed method research study will involve the participants' initial feedback with regards to current PD practices. Subsequently, participants will give feedback on two bespoke face-to-face PD classes led by the University. The continuation of virtual PD sessions, run by the LA, will run alongside. The data collection method will be through questionnaires that are designed around current research in effective PD. From this study, the research acquired will assist the University and LA in developing/refining effective D&T PD while also helping D&T teachers to cultivate sustained lifelong learning goals.

POSTER 10: Electronic Sentences: a Systems Development Tool for Young Children

Torben Steeg, Manchester Metropolitan University, torben@steeg.co.uk
Ben Sedman, Manchester Metropolitan University, b.sedman@mmu.ac.uk

This poster describes Electronic Sentences (ES). This is a suite of software and hardware tools, along with supporting curriculum materials, that uses high-level electronic elements to allow young children to easily develop age-appropriate systems to solve real-world problems. As the name suggests, systems are created by assembling grammatically correct sentences that are scanned to create a corresponding electrical system. ES thus helps children develop literacy skills, logical thinking, design thinking and systems thinking. ES is designed to be used in conjunction with a wide range of modelling materials, which teachers will select with an eye to suitability for the children using the system. ES is being developed by a US/UK team. The target age for ES is anywhere between, in England, EYFS and Key Stage 1 and, in the US from grades pre-k-5. The design has focussed on useability for the youngest children in these ranges, i.e., children from 4 years on, while retaining attractiveness for older children, with the acknowledgement that teachers will use their judgement about when best to introduce ES. Limited trials of a prototype, fully working, system have taken place in US classrooms. This paper will, along with describing the ES system and its design aims, report on initial trials in English classrooms. It will explore the effectiveness of the system in achieving its multiple aims (the development of literacy skills, logical thinking, design thinking and systems thinking) and, in the light of these trials suggest necessary developments in the various elements of hardware, software and courseware that will be required before the product is made widely available.

POSTER 11: Primary to Secondary Engineering Learning: A Framework for International Consideration

Greg Strimel, Purdue University, gstrimel@purdue.edu
Deana Lucas, Purdue University, lucas158@purdue.edu

The teaching of engineering has made its entrance into the subject of Design & Technology Education (DTE) around the world over the past few decades. This inclusion has been particularly true for the United States which refers to its DTE-related subject as Technology & Engineering Education. The inclusion of engineering has likely been due to the closely aligned epistemologies and classroom practices between engineering and DTE. But, while engineering has been emphasised in primary and secondary schooling, there has also been limited guidance for articulating how engineering could/should be taught, both authentically and equitably, across the years of school and how it is connected with other school subjects. To aid in this effort, a Framework for P-12 Engineering Learning was formed through over 3 years of iterative research and development work and published by the American Society of Engineering Education (2020). This framework was created to help provide a unifying vision and guidebook to inform decisions for improving the coherency and equity of engineering teaching and learning across the country. In addition, throughout this process, Engineering Performance Matrices (EPMs) were generated to offer sample blueprints of how the engineering concepts and sub-concepts identified within the framework could build upon each other to support teachers in creating authentic learning experiences that increase in sophistication over time—enabling students to achieve any designated engineering-related performance tasks or standards related to engineering/technology. The goal of this poster presentation is to share the framework, and the EPMs, with the international DTE community for consideration of any useful components that could be adapted for their own efforts related to engineering learning. The poster will specifically highlight engineering literacy elements of the framework, the EMPs, and examples of ways in which this information can be used to establish engineering-focused instruction in the pursuit of engineering-literacy for all.

POSTER 12: Design & Technology Education: What can we do to Influence Transdisciplinary Undergraduate Learning?

Greg Strimel, Purdue University, gstrimel@purdue.edu
Deana Lucas, Purdue University, lucas158@purdue.edu

Creating new ways to position Design and Technology (DT) teacher preparation programs in higher education can be considered critical today. For example, in the United States, the few remaining DT-related teacher programs can be in jeopardy of supporting the school subject as a result of teaching workforce declines. But, while some may view that DT programs are no longer relevant in parts of the world today, there can be an opportunity to leverage and make pertinent DT content/practices beyond teacher preparation. New DT approaches can be important to consider, not only to just sustain the remaining programs, but to also create new educational experiences that provide valuable skills/knowledge to a broader audience. In doing so, teacher programs can deliver DT experiences across college campuses that many students may no longer have access to in secondary schools—due to the aforementioned teacher workforce concerns. These DT learning experiences can involve the content/practices related to designing/making/innovating as well as the pedagogical approaches that support transdisciplinary learning. With a variety of educational transformation initiatives happening at universities, DT programs can help shape the way that undergraduate learning occurs. So how do DT programs leverage their value related to transdisciplinary learning through design/innovation practice to reach new audiences while also sustaining programs that develop teachers? To provide an answer, this poster will highlight a transdisciplinary program, titled Mission Meaning Making (M3), that was developed to provide a new cross-college learning experience for undergraduate students focused on design and innovation. The M3 program has been created to synergize the key strengths of three partnering units/disciplines (DT, anthropology, and business) to prepare undergraduates for addressing contemporary challenges in innovative, and transdisciplinary ways. The poster will provide details/research related to the M3 program and explore how DT can strive to make a broader impact on campuses.

POSTER 13: Technology Education Is Important for Achieving Sustainable Development

Maria Sundler, KTH Royal Institute of Technology, marisand@kth.se
Susanne Engström, KTH Royal Institute of Technology, sengstro@kth.se
Annica Gullberg, KTH Royal Institute of Technology, gullbe@kth.se
Helena Lennholm, KTH Royal Institute of Technology, lennholm@kth.se

In 2015 all 193 United Nations Member States agreed on 2030 Agenda for Sustainable Development with its 17 Sustainable Development Goals (SDGs) with the purpose to end poverty, ensure prosperity, and protect the planet. Technology and sustainable development are intertwined. The term ""double-edged sword"" has often been used to describe technology, as it can be both helpful and harmful. But to what extent is technology significant for sustainable development and what content can technology education have in relation to sustainable development? This study examines what technology content can be discerned in the sustainable development goals, SDGs, in order to detect possible content for technology education. The 17 SDGs include 169 targets since every SDG are defined with ""Outcome targets"" and ""means of implementation targets"". All 169 SDGs targets were analyzed through content analysis. A category system was developed from the definition of technology by Rossouw et.al (2010) and DiGironimos's (2011) to discern technology content in the SDGs. The results show that the achievement of each and every 17 Sustainable Development Goals in one way or another relies on our use of technology and our development of technology. Teaching with a sustainability perspective creates meaningful content for technology education, where current news and topics can be a starting point. Such teaching can provide students with necessary knowledge towards making well-grounded decisions based on facts, as both consumers and global citizens.

Conference Worskhops

WORKSHOP 1: Animated Film Bridging Science, Technology, and Art with the UN Sustainable Goals

Barbro Bergfeldt, Erik Sjöstedt & Ulrika Sultan.

This is an interactive workshop where participants can experience making an animated short film using iPad and Stop Motion. By making a film the participants will be aware of the learning process and interaction between different disciplines. Participants will use clay to visualise what technology can be.

Room: Emma Holt Suite

Numbers: max. 10

WORKSHOP 2: Comics as Pedagogy: Ways of Knowing, Expressing and Communicating

Jane Burn, Deaglán Campbell, Clodagh Reid, and Niall Seery.

This workshop is a collaborative effort among a technology educator, a designer, and a librarian, aiming to harness the power of comics for future thinking. Comics are viewed as an ideal medium for visualizing and communicating ideas, transcending textual literacy barriers. The workshop explores multiple approaches, from teaching students to create comics to using them as tools for teaching various subjects and levels. It emphasizes the accessibility and engagement comics offer, making complex information more understandable. The workshop seeks to bridge different disciplines, demonstrating how comics can be applied in technology, design, and library science, ultimately highlighting their value in education and fostering creativity.

Room: June Henfry Suite

Numbers: max. 20

WORKSHOP 3: Roundtable discussion on 'Maker Education Meets Technology Education: Reflections on Good Practices'

P John Williams, Marc de Vries, Remke Klapwijk, Wendy Fox-Turnbull, Jeff Buckley, HildaRuth Beaumont (formerly known as David Barlex) & Marten Westerhof.

During this roundtable discussion, two fields will meet, technology education with its long history, and Maker Education, a relative new shoot in the educational field. Both focus on learning through making and both value agency and motivation of learners. During the round table we will invite all participants to reflect with us on maker education practices across the world and relate these insights to technology education. The purpose of this session is to understand and analyse the kind of informal and formal educational activities that take place under the umbrella of the Maker Movement and then relate this to the field of Technology education to uncover what researchers, innovators and teachers in this field can learn from the principles, ideas and practices that are central to the Maker Movement and vice versa. The session is moderated by Remke Klapwijk, Delft University of Technology, and co-editor of book 'Maker Education Meets Technology education; Reflections on Good Practices'.

Room: Eleanor Rathbone Hall

Numbers: max. 35

Pupils 'Attitude Toward Technology (aka PATT) is an international community of educational researchers whose mission is to generate and share knowledge about design, technology and engineering education. The annual meeting of the community is the PATT Conference brings together researchers, authors and teachers of design, technology and engineering from around the world. Recent conferences have been held in Newfoundland (PATT39), Finland (PATT38), Malta (PATT37) and Ireland (PATT36). The 2023 conference will be the 40th event in the history of PATT, which derives its name from a study begun in The Netherlands in 1984 to determine the attitude toward and concept of technology held by students aged 12-15 years.

The main theme for PATT40 is *"Diverse Experiences of Design and Technology Education for a Contemporary and Pluralist Society"*, inviting delegates to present original research and scholarship exploring axiological, epistemological, and ontological aspects of the subject. Four sub-themes break the theme down into strands, focusing on philosophy and culture (Strand I), curriculum, pedagogy, and assessment (Strand II), evidence-based practice (Strand III) and teacher education and development (Strand IV):

I. Diverse and inclusive ways of knowing and being in design and technology;
II. Exploring and advancing teaching and learning for design and technology education;
III. Measuring impact of design and technology education in and beyond the classroom;
V. Approaches to teacher preparation and development in design and technology education;

RESEARCHING D&T

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