SECONDARY TEACHER AND TEACHER EDUCATOR PERSPECTIVES ON ‘DEMONSTRATION’ AS A SIGNATURE PEDAGOGY FOR DESIGN AND TECHNOLOGY: IMPLICATIONS FOR INITIAL TEACHER EDUCATION

MATT MCLAIN

A thesis submitted in partial fulfilment of the requirements of by Liverpool John Moores University for the degree of Doctor of Philosophy by Published Work

This research was carried out at Liverpool John Moores University

December 2022

Table of Contents

List of Figures

List of Tables

Acknowledgements

First, and foremost, I thank my wife Mel and sons Drew and Owen for their patience during my career as a teacher and a teacher educator. I would not have managed to do what I do without you! Second, thanks go to my parents, Dr Henry and Wendy McLain, who instilled in me a growth mindset and determination to succeed from an early age. I am also grateful for the opportunity to work and write with colleagues as we worked out how to research and publish together; especially Dr Dawne Irving-Bell, Dr David Gill, Dr Alison Hardy, and David Wooff (and the other co-authors of four of the articles in my portfolio for this PhD by Published Work). Writing with my peers has been an apprenticeship by stealth! These represent but a few of the colleagues with whom I have had the honour of working on conference presentations, articles, policy documents, and other scholarly works. In support of my application, write-up, and viva voce for PhD by Published Work at LJMU, I thank Professor Michael Thomas and Dr Anne-Marie Bartlett for the advice and encouragement along the way – it has been a long and winding road, but I got there in the end! I consider myself privileged to have been part of the Pupils' Attitudes Towards Technology (PATT) conference community over the last decade, which has provided me with support and encouragement as a developing researcher – there are too many people to name, but I hope you know how important you are to emerging design and technology educational researchers. The hundreds of pupils I taught as a teacher and teachers I had a hand in training have had an immeasurable formative impact on my values and knowledge as a D&T teacher, teacher educator and researcher. For my career progression from teaching in schools to educating generations of teachers in university, I thank my two heads of department, Dave McLean (De La Salle High School) and Tony Simpson (Rainford High Technology College), who gave me space and encouragement to develop as a teacher. Andy Mitchell, as programme leader for my Master of Arts at Sheffield Hallam, and later at the Design and Technology Association, you made me aware of opportunities and ideas that I didn't know existed at the time. To everyone else unmentioned above, I apologise and thank you.

Abstract

This research consists of eight peer-reviewed journal articles and contributes to the under-theorised pedagogy of demonstration in design and technology (D&T). Demonstration is presented as a signature pedagogy, commonly used for teaching practical skills (or procedural knowledge). The aims of the studies represented in this research include exploring secondary teacher and teacher educator views, addressing the apparent lack of evidence and systematic research into D&T pedagogy and practice. The literature suggests that diverse theoretical perspectives are associated with teachers' views on modelling and explaining in D&T, including constructivism, social learning, and cognitive load; with the expert teacher adopting a more directive and restrictive approach during demonstration. The overarching research questions were concerned with pre- and in-service teacher and teacher educator views on effective approaches to demonstration and the use of a signature pedagogies framework to evaluate and select appropriate teaching methods. A variety of research methods were used in the studies, including autoethnography and mixed-methods questionnaires, with the particular use of Q Methodology to explore the subjective views of participants regarding effective demonstration. The sampling was non-probability, and research participants represented in the portfolio of articles included 202 Key Stage 3 pupils from five secondary schools in North West England, seven teachers and 11 teacher educators from across England and Scotland, and 192 preservice teachers in Merseyside. The findings indicate that demonstration was considered a teacher-led and relatively restrictive form of modelling, with participants ranking more expansive strategies lower in importance, including those that promote the consolidation of learning and facilitation of autonomy. Later studies revealed two pedagogical archetypes for D&T and Science, Technology, Engineering and Mathematics (STEM) educators: the first, a more behaviourist teacher-as-expert approach and the second a more constructivist teacher-as-facilitator led approach. However, these two perspectives were not expressed as mutually exclusive, the differences being subtle and nuanced. This research suggests that teachers should consider demonstration as a surface structure (teaching method) on an expansive-restrictive pedagogical continuum, with an understanding of its benefits and limitations, as part of a broad pedagogical repertoire. Further research is needed on the impact of various approaches to demonstration in D&T, including frontloading, just-in-time, and after-failure approaches, and the impacts they have on students' capability and learning.

Keywords

Curriculum, Demonstration, Design and Technology, Expansive-Restrictive Continuum, National Curriculum, Pedagogy, Pragmatism, Q Methodology, Signature Pedagogies, Subjectivity, Teacher Modelling.

Portfolio of Publications

Articles for consideration for PhD by Published Work:
All papers are either solo or lead authored publications. The weightings for the contribution to joint publications are indicated in *Appendix 3: Statements of Contribution from Co-Authors*. There are a total of 8 papers, equivalent to 7.3 solo authored pieces. The table presents the papers in the original online publication order. Paper 4 was first published in 2019 and was assigned to an issue in 2021. Paper 8 was published online in 2021 and is yet to be assigned to an issue.

List of Published Works

Paper 1 McLain, M. (2012). An (auto)ethnographic narrative of the teaching of designing within Design and Technology in the English curriculum. *Procedia Social and Behavioral Sciences, 45,* 318-330. https://doi.org/10.1016/j.sbspro.2012.06.568

Paper 2 McLain, M., Bell, D., Smith, J. and Martin, M. (2014). Reviewing the Impact of the National Strategies Design and Technology Framework for Key Stage Three. *The European Journal of Social and Behavioural Sciences, IX(2),* 1355-1366. https://doi.org/10.15405/ejsbs.119

Paper 3[1] McLain, M. (2018). Emerging perspectives on the demonstration as a signature pedagogy in design and technology. *International Journal of Technology and Design Education, 28(4),* 985-1000. https://doi.org/10.1007/s10798-017-9425-0

Paper 4[2] McLain, M. (2021). Developing perspectives on 'the demonstration' as a signature pedagogy in design and technology. *International Journal of Technology and Design Education, 31(1),* 3-26. https://doi.org/10.1007/s10798-019-09545-1

Paper 5 McLain, M., Bell, D., Wooff, D. and Morrison-Love, D. (2019). Humanising the design and technology curriculum: Why technology education makes us human. *Design and Technology Education: An International Journal*, *24(2),* 8-19. https://ojs.lboro.ac.uk/DATE/article/view/2610

Paper 6 McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2019). How technology makes us human: cultural and historical roots for design and technology education. *Curriculum Journal, 30(4),* 464-483. https://doi.org/10.1080/09585176.2019.1649163

Paper 7 McLain, M., McLain, D., Wooff, D. & Irving-Bell, D. (2021). Preservice Teachers' Perspectives on Modelling and Explaining in STEM Subjects: a Q Methodology Study. *Techne: Research in in Sloyd Education and Crafts Science, 28(2),* 367–374. https://journals.oslomet.no/index.php/techneA/article/view/4292

Paper 8 McLain, M. (2021). Towards a signature pedagogy for design and technology education: a literature review. *International Journal of Technology and Design Education*, Online First, 10 April. https://doi.org/10.1007/s10798-021-09667-5

[1] First published online 1st September 2017.
[2] First published online 4th September 2019.

Supporting Scholarly Works[3]

Paper 9[4] DfE (2015a). *Design and Technology GCE AS and A Level Subject Content* [policy document]. Retrieved from https://www.gov.uk/government/publications/gce-as-and-a-level-design-and-technology

Paper 10[5] DfE (2015b). *Design and Technology GCSE Subject Content* [policy document]. Retrieved from https://www.gov.uk/government/publications/gcse-design-and-technology

Paper 11 McLain, M. (2019). Helping new D&T teachers to analyse and develop knowledge and understanding in design and technology (product design). In S. Lawson & S. Wood-Griffiths (eds). *Mentoring beginning design and technology teachers: a practical guide*. Abingdon, UK: Routledge. ISBN: 9781138541108

Paper 12 McLain, M. (2021). Key pedagogies in design and technology. In A. Hardy (ed), *Learning to teach design and technology in the secondary school: a companion to school experience* (4th Edition). Abingdon, UK: Routledge. ISBN: 9780367336813

Paper 13[6] McLain, M. (in press). What's so special about design and technology anyway? Exploring contemporary and future teaching using a signature pedagogies discursive framework. In A. Hardy, *Debates in Design and Technology Education*. Abingdon, UK: Routledge.

[3] These publications illustrate how my research informs and is informed by my wider scholarly work as a teacher educator and curriculum designer at a national level.

[4] Department for Education policy document, co-drafted with Bob Welsh (Retired Educational Consultant).

[5] Ibid.

[6] To be published in 2022.

Abbreviations

AS/A Level	Advanced Subsidiary / Advanced Level
AST	Advanced Skills Teacher
BEI	British Education Index
BERA	British Educational Research Association
CJ	Curriculum Journal
CLT	Cognitive Load Theory
CPD	Continuing Professional Development
D&T	Design and Technology
D&TA	Design and Technology Association
DATE	Design and Technology Education: An International Journal
DBS	Disclosures and Barring Service
DfE	Department for Education[7]
DfES	Department of Education & Skills[8]
DI	Direct Instruction
EV	Eigenvalue
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
HEI	Higher Educational Institution
ICT	Information and Communication Technology
IJTDE	International Journal of Technology & Design Education
ITE	Initial Teacher Education
KS3	Key Stage 3
LJMU	Liverpool John Moores University
MKO	More Knowledgeable Other
NC	National Curriculum
NQT	Newly Qualified Teacher
PCK	Pedagogical Content Knowledge
RO	Research Objective
RQ	Research Question
STEM	Science, Technology, Engineering & Mathematics
UK	United Kingdom

[7] The name of the government department 2008 to present.

[8] The name of the government department 2001 to 2008.

1 Introduction

This PhD by Published Work contributes to, and leads, original knowledge of the under-theorised pedagogy of demonstration in design and technology (D&T). Demonstration is a teaching method that “focuses on knowledge transfer of technical processes and the practical application of knowledge - demonstrated by the teacher and replicated by the learner” (McLain, 2018, p. 986). It involves modelling by an expert teacher showing novice learners “how to do something and making explicit the thinking involved” (DfES, 2004b, p. 3), where the verbal explanation emphasises sequence (DfES, 2004c).

The studies on demonstration as a signature pedagogy in D&T education emerged from discussions with preservice teachers in Liverpool (UK) working on assignments for their initial teacher education (ITE). These conversations revealed an apparent lack of available literature on certain aspects of D&T pedagogy, specifically around the process of demonstrating practical skills in the classroom. An early literature search of related pedagogical texts and journal articles confirmed that very little had been written about demonstration or its pedagogical ‘parent’, teacher modelling, in a D&T context (McLain et al., 2015). Yet Petrina describes demonstration as ‘‘the single most effective method for technology teachers’’ (2007, p. 1). The experience of these preservice teachers was that demonstration was a key teaching method used frequently by teachers in their placement schools. Knowledge of how to demonstrate was either assumed through experience or inculcated through university-based training and working alongside a school-based mentor.

This identification of the research gap led to the portfolio of eight peer-reviewed research articles presented here, which explore the nature of curriculum and pedagogy in D&T with a particular emphasis on how practical skills (or procedural knowledge) are taught. Overall, these studies reveal that teachers and teacher educators view demonstration as a more restrictive and teacher-led teaching method. This has important implications for how teaching methods are selected with different learning outcomes in mind, particularly in a subject that aims to "develop the creative, technical and practical expertise" (DfE, 2013a, p. 234). In this introduction to my portfolio of peer-reviewed articles, I will outline the key findings and discuss the implications for future praxis. This includes the development of a discursive framework based on a hybrid of concepts relating to signature pedagogies and an expansive-restrictive continuum for promoting dialogue between educators on how D&T is taught and learnt in secondary schools.

Surface Structure	"…concrete, operational acts of teaching and learning, of showing and demonstrating… of interacting and withholding, of approaching and withdrawing…"
Deep Structure	"…, a set of assumptions about how best to impart a certain body of knowledge and know-how…"
Implicit Structure	"a moral dimension that comprises a set of beliefs about professional attitudes, values, and dispositions…"

Table 1 The Structures of Signature Pedagogies (Shulman, 2005, pp.54-55)

Signature pedagogies are "characteristic forms of teaching and learning" (Shulman, 2005, p. 52) within a specific discipline and are comprised of three structures: *surface* (concrete acts of teaching), *deep* (assumptions about how best to teach) and *implicit* (underpinning attitudes, values, and dispositions) (Table 1). Papers 3, 4 and 7 focus on demonstration as a *surface structure* (or teaching method) in D&T. It is important (and noteworthy) to emphasise that 'surface' in this instance should not be interpreted as 'superficial' or inferior, but rather as being activities and behaviours that are observable in the classroom context. For this study, pedagogy is broadly

defined as the “interactions between teachers, students, and the learning environment and the learning tasks” (Murphy, 2008, p. 35).

Demonstration by an expert is a common approach to social learning, traceable from the master-apprentice relationships to modern schooling (e.g. Claxton, Lucas & Webster, 2010; Sennett, 2008); yet it has not received significant attention in D&T research or its National Curriculum (NC) predecessors. Demonstration, as a more teacher-led pedagogical method, has significant implications for how teachers plan and teach the subject, using a range of both expansive and restrictive approaches. Given the focus in the NC Purpose of Study statement on “creativity and imagination” (DfE, 2013a, p. 234), Papers 3 and 4 suggest that an overreliance on more restrictive teaching methods like demonstration potentially undervalues the facilitation of autonomy and the consolidation of learning.

1.1 Coherence and Significance

The coherence of the research portfolio derives from four core articles focusing on signature pedagogies and demonstration in D&T education (McLain, 2018, 2021a, 2021c; McLain et al., 2021), supported by two articles that explore the philosophical and practical tensions between design and making (McLain et al., 2019a, 2019b). This is relevant as the subject has evolved from a making-centric paradigm (where demonstration was embedded), towards a more design-focused curriculum (where a wider pedagogical repertoire is needed) (Atkinson, 1990, in press; McLain et al., 2019a). Nonetheless, demonstration continues to be a key D&T teaching method, focused on developing skills (and procedural knowledge) through teacher modelling and explanation (McLain, 2018; Petrina, 2007). The remaining two articles explore the tensions between knowledge and experience in the post-reform secondary D&T

curriculum, where the dominant ideologies are influenced by the concept of so-called powerful knowledge (Biesta, 2014; Muller & Young, 2019; White, 2018) and the English Baccalaureate (Long & Danechi, 2019).

1.2 Context

Through professional dialogue with school-based D&T mentors from Greater Merseyside secondary schools and D&T teacher educators through an email group in the academic year 2013/14, what was initially a checklist of points for mentors to look for when observing preservice teachers, developed into 62 statements. The resultant statements detailed a range of possible features of an effective demonstration. Initially, the set of statements was used with seven D&T teachers to explore their subjective values and beliefs about effective demonstration. An early analysis of the findings was presented at the Pupils' Attitudes Towards Technology (PATT) conference by McLain et al. (2015). These findings were then analysed in-depth and presented in Paper 3, a peer-reviewed journal article (McLain, 2018). This study identified views of demonstration as a largely restrictive approach where the teacher plays a leading role, rather than a more expansive approach where learner autonomy is encouraged (Fuller & Unwin, 2003). Restrictive, in this context, should not be construed as a negative attribute, but rather an acknowledgement of the necessary and deliberate limiting of learners' autonomy when focusing on specialist knowledge, where it is considered important that specific sequences or relationships are followed by the learner. It is a more teacher-centric approach to teaching and learning, as opposed to expansive approaches where learners act with a greater degree of autonomy. The same set of statements was then used with 11 D&T teacher educators, with early analysis presented at the PATT conference (McLain, 2016) and subsequently analysed in-depth in Paper 4, as a peer-reviewed article

(McLain, 2021a). This study identified 32 distinguishing statements, with less consensus between participants. These ‘distinguishing’ statements were then used with 192 secondary preservice teachers and the findings presented in Paper 7 (McLain et al., 2021).

1.2.1 Research Questions

One driving question that preceded and informed the research questions (RQs) for these studies came from student teachers asking, “Where can I find research on demonstration in D&T?” Discussion of this important aspect of D&T pedagogy was absent from the available literature. Therefore, the overarching RQs that have guided my research, are:

> **RQ1.** What do D&T educators in the state secondary school sector, in England, perceive to be effective strategies for the ‘demonstration’ of skills?
>
> **RQ2.** How does a signature pedagogies framework enable exploration of D&T pedagogies to evaluate and select appropriate teaching methods?

RQ1 aimed to address the lack of systematic research in D&T, exploring educator beliefs about effective practice. The three Q Methodology studies (McLain, 2018, 2021c; McLain et al., 2021) in my portfolio answer this question by analysing teacher and teacher educator views on effective demonstration of practical skills in D&T. The literature review (McLain, 2021c) informs the signature pedagogy framework used in this PhD, in response to **RQ2**.

1.2.2 Aims and Objectives

This PhD by Published Work emerges from the context of a decade of curriculum reform in England (from 2011 onwards) and aims to address the assumption that practical subjects have “weaker epistemological roots” (DfE, 2011, p. 24). Through

professional reflection (Paper 1), empirical research (Papers 2, 3, 4, 7 and 8) and philosophical discourse (Papers 5 and 6), it contributes to the D&T pedagogical research and knowledge base by:

RO1. Analysing the established pedagogy of demonstration concerning the aims of D&T in the current NC programme of study;

RO2. Exploring teacher and teacher educator perspectives on how secondary D&T is taught in England;

RO3. Contributing to the apparent lack of evidence and systematic research to support D&T's educational aims.

My portfolio of peer-reviewed journal articles makes a significant contribution to an under-researched and under-theorised aspect of D&T (cf Harris & Wilson, 2003). The contributions to the field include addressing the research gap on demonstration, as a key D&T teaching method, and the theorisation of the subject. It proposes a new pedagogical framework for secondary D&T teacher education, informed by the concept of signature pedagogies.

1.3 Thesis Structure

The following sections introduce the portfolio of eight peer-reviewed journal articles for the PhD by Published Work. Section 2 outlines relevant themes from literature followed by Section 3, which provides a critical overview of the research approaches adopted across the studies, with a particular focus on Q Methodology. Section 4 presents and discusses the findings as they relate to the RQs, stated in Section 1.1.2 (page12). Finally, Section 5 draws together conclusions and implications from the studies, including the role of demonstration in D&T as a teaching method (surface structure) as part of the subject's wider signature pedagogies. The research

participants for my portfolio of articles included 202 Key Stage 3 pupils from five secondary schools in North West England (Paper 2), alongside seven teachers (Paper 3) and 11 teacher educators (Paper 4) in the UK and 192 preservice teachers (Paper 7) in Merseyside.

2 Literature Review

In this section, I outline relevant themes from the literature under the headings of *background*, *educational theories,* and *signature pedagogies*. In the absence of systematic research into D&T pedagogy (Harris & Wilson, 2003), and demonstration in particular (McLain, 2018; McLain et al., 2015), these themes scope out a relevant knowledge base for the context of this PhD by Published Work.

2.1 Background

D&T emerged as a school subject in the late 1980s, encapsulated in the first NC programme of study (PoS) to be published in England (Atkinson, 1990, in press; DES/WO, 1990). This original PoS, entitled 'Technology', included elements of craft design and technology (CDT), home economics, art and design, business studies and the new subject of information technology (DES/WO, 1989). The second iteration of the PoS (DfE, 1995) reformed the subject from a collection of technology subjects into D&T, which incorporated the variety of materials and technologies experienced under the former, gendered, subjects of CDT and home economics, with an increasing focus on design. At the heart of D&T, from its beginnings through the subsequent reforms (cf. DfE, 2013b; QCA, 2004, 2007), is the idea of realising human capability through technology, within a designing-making-and-evaluating paradigm. Writing about technology education in schools, Black and Harrison (1985) outlined the importance of developing practical capability through tasks that engaged

pupils with resources (including knowledge, skills, and experience) and awareness (including perception, understanding and critical thinking). Capability is concerned with the ability “to perform, to originate, to get things done…” (p. 6), and D&T consciously and transparently draws on knowledge from other NC subjects. The committee advising on the introduction of D&T to the curriculum in England and Wales was clear that it was a subject that balanced propositional knowledge and action knowledge, recognising the inherent tensions and need for further research (DES/WO, 1989). As a subject concerned with knowledge for action (McLain et al., 2019a, 2019b), pedagogical approaches are needed to develop procedural knowledge (know-how), such as ‘the demonstration’. These are as important and prevalent as those that develop conceptual knowledge. Ryle (2000, 1949) described the difference between conceptual and procedural knowledge as *knowing that* and *knowing how*, respectively. Rather than viewing skill as separate and distinct from knowledge, this perspective (adopted in these studies) sees know-how, or skill, as one side of the knowledge ‘coin’. Therefore, skill and procedural knowledge are presented together in the discussions on demonstration in this thesis (McCormick, 1997; Lewicki, Czyzewska & Hoffman, 1987). As a subject concerned with capability, knowing how to apply knowledge is central to curriculum design and pedagogical approaches.

2.2 Educational Theories

Demonstration can be considered through the lenses of social constructivism (e.g. Vygotsky, 1978), social learning (e.g. Bandura, 1977), cognitive load (e.g. Kirschner et al., 2006), and psychomotor taxonomies of educational objectives (e.g. Simpson, 1972). The role of tools, both physical and conceptual, is a key tenet of social constructivist theories, having the power to affect how we think and act both as

individuals and as communities (Tappan, 1997; Vygotsky, 1978). The ‘‘creation of external technology’’ is associated with mastery and development in Vygotskian theory (Daniels, 2005), where technology and society are key human activities that go hand in hand (McLain et al., 2019a, 2019b). At the beginning of my investigation of teacher views on demonstration (Paper 3 - McLain, 2018), social constructivist theories were used to explain how learners internally reconstruct observation of an external activity. In this way, procedural knowledge is passed from a more knowledgeable other (MKO) to a novice. Social constructivist theory highlights the potential for the overuse of scaffolded or teacher-led approaches (like demonstration, where the MKO structures or simplifies what is being taught as new material, to reduce the need for learners to recall or speculate based on prior learning. The impact of an overly scaffolded approach is to limit opportunities for consolidation of learning and development of autonomy

After Paper 3 considered demonstration from a social constructivist theory, Paper 4 (McLain, 2021a) explored it from the perspectives of cognitive load theory (CLT) and direct instruction (DI), which highlighted the potentially detrimental impact of requiring learners to process large amounts of new knowledge in their working memory (Kirschner, Sweller & Clark, 2006). Within the cognitive sciences literature, the commonly shared view is that teacher-led approaches like DI should precede more learner-centric ones, like discovery learning (Mincu, 2015; Rowe, 2006). Furthermore, research such as Hattie’s (2008) meta-analyses appears to support the high level of effectiveness of DI for students’ learning. DI is often considered to be an opposing approach to so-called constructivist methods, but should not be conflated with “didactic teacher-led talking from the front” (p. 204). Rather, it is more correctly

viewed as an overarching approach to lesson design, where learning intentions and success criteria are shared with learners, the teacher models and/or explains a concept or process, and the learners apply and reflect on what they have done and learnt. Some theorists, such as Martin (2016), suggest a more nuanced approach than others with more polarising views, such as Kirschner et al. (2006), where less structured pedagogies are adopted, bearing in mind cognitive load. However, a recent systematic review questions the strength of the claims from cognitive science as evidenced in applied, classroom-based research (EEF, 2021).

Social learning theory (SLT) potentially bridges the perceived gap between the constructivist and behaviourist perspectives (Bandura, 1977), recognising the social context for learning through observation, imitation and modelling. SLT highlights the distinction between *acquiring* and *performing* knowledge, akin to what Ryle (2000, 1949) describes as *knowing that* (conceptual knowledge) as opposed to *knowing how* (procedural knowledge). When demonstrating practical knowledge, such as the correct use of a tool, the teacher is relying on the learners' ability to observe and acquire a conceptual understanding, constructing a mental model. Without the opportunity to perform and retrieve what has been observed and is held in the learners' working memory, the new knowledge may not be encoded into their long-term memory (Brown, Roediger & McDaniel, 2014). Therefore, demonstration in D&T, like the stages described in DI, is typically followed by learners undertaking guided practice to consolidate skills (and procedural knowledge). This is a particular challenge for *frontloaded* demonstrations, where either a complex process is being modelled and learners are expected to hold knowledge in their working memory, or where there is a delay between the teacher modelling and the learners performing

through guided practice. Both cases require learners to encode and retrieve knowledge to and from long-term memory (Baddeley, 2000). However, the advantage of adopting a frontloaded approach is that it presents a holistic demonstration of a complete process as opposed to a *just-in-time* approach that breaks a process into discrete stages. Whilst just-in-time demonstrations reduce cognitive load (Martin, 2016), they increase pupils' reliance on the teacher and interrupt guided practice and learner autonomy.

When Bloom et al. presented their taxonomy of learning outcomes for the cognitive domain, which dealt "with the recall or recognition of knowledge and the development of *intellectual* abilities and skills" (1956, p. 7), they identified two further domains: the affective and the psychomotor. Members of the original research team went on to describe the affective domain (Krathwohl, Bloom & Masia, 1964), which focused on emotion-based learning, including developing attitudes and values. However, the team did not see the value of expanding on the psychomotor, stating "we find so little done about it in secondary schools or colleges, that we do not believe the development of a classification of these objectives would be very useful at present" (Bloom et al., 1956, pp. 7-8). This emphasises the lack of research into practical or action-based learning at the time. Whilst it could be argued that this problem persists to the present day (evidenced by the aforementioned lack of research into demonstration in D&T), the psychomotor domain has since been described by Dave (1967), Simpson (1972), Harrow (1972), and Marranzo and Kendall (2007). The stages for each of these psychomotor domains differ in how the researchers label and categorise activities, but they are broadly similar to the observation, imitation and modelling described by SLT. The psychomotor domains

extend beyond the initial learning experience by the novice, describing how skills develop from a more mechanical replication towards a more fluent and creative expression. The taxonomies of the psychomotor domain are useful frameworks for thinking about the demonstration of new skills by the teacher to the learners' guided and independent practice and beyond, to developing expertise. Papers 3 (McLain, 2018) and 4 (McLain, 2021a) were informed by CLT, DI, SLT and the psychomotor domains, in how they explore demonstration as a signature pedagogy in D&T, focused on the transmission of skills (and procedural knowledge). In the next section, I will outline the concept of signature pedagogies, drawing on the work of Lee Shulman, Paper 8 (McLain, 2021c) and work for a future chapter in an edited book (McLain, in press).

2.3 Signature Pedagogies[9]

The concept of signature pedagogies has helped to locate demonstration within the pedagogical lexicon of D&T. It is a term that has received some attention in the recent D&T literature from a design perspective (e.g., Stables, 2020; Noel & Liub, 2017; Osmond & Tovey, 2015), but this thesis is unique in applying the concept to demonstration and creating a framework based on the 'structures' outlined below.

During my investigation of teacher and teacher educators' views, in Paper 3, I wrestled with whether demonstration was a signature pedagogy (cf. McLain, 2018, p. 24), as it is not unique to D&T. However, in the light of Shulman's (2005) structures of signature pedagogies outlined above in Table 1, it can be described as a surface structure - that is, an observable and overt act of teaching. Furthermore, the

[9] This section is adapted from Paper 13 (supporting scholarly work) scheduled to be published in 2022.

systematic literature review in Paper 8 (McLain, 2021c) explored facets of signature pedagogies, clarifying the relationships between beliefs about the best approaches to learning in particular disciplines (deep structures) and the discrete teaching methods or acts of teaching (surface structures). Thus, it became more than a convenient theory in these studies (as it was in the beginning), providing an intellectual tool for stimulating reflexivity, challenging assumptions, and checking biases.

Shulman introduced the term *signature pedagogy*, in response to studying learning in the professions (including engineering, law and medicine), to define the characteristic pedagogical approaches used within disciplines. These are not necessarily the most effective, but they are the most widely accepted and used approaches to disciplinary education and training. Signature pedagogies feature the development of capability (knowledge in and for action) and a degree of uncertainty (McLain, 2021c). Therefore, a signature pedagogy will be defined by how a discipline applies its body of knowledge in contexts where the outcome is not predetermined. In D&T, this is seen most clearly in 'the project', where the assessment focus is as much on the process as it is on the product. Where demonstration is described as a *surface* structure, project-based learning is a *deep* structure that is supported by it, alongside a range of other teaching methods.

This way of looking at pedagogy built on Shulman's earlier work on pedagogical content knowledge (PCK), which focused on the complexities of teacher knowledge (1986). Whilst PCK is interested in the relationship between subject *content*, *pedagogy* and *curriculum*, and how particular concepts and processes are taught,

signature pedagogies focus on the pedagogical approaches that are pervasive across a discipline (i.e., common approaches that can be routinely observed in classrooms from school-to-school). PCK is concerned with teachers' knowledge of how to teach specific subject content, including awareness of the associated difficulties and misconceptions associated with concepts or processes, and the curriculum resources available to teach it. Conversely, signature pedagogies focus on the activities of teaching and learning themselves, and the associated, underlying assumptions; taking a more philosophical stance than PCK. Both frameworks have value in teacher education and professional development, but in the context of this PhD by Published Work, I present signature pedagogies as a discursive tool for deconstructing and examining practice in D&T education.

Signature pedagogies are concerned with learning to think, learning to perform, and learning to act with integrity, or "habits of the mind, habits of the heart, and habits of the hand" (Shulman, 2005, p. 59). As D&T is a subject predicated on capability, or knowledge in/for action, the triple concern with knowing, doing, and valuing has resonance with how it is taught around the world through various curricula (Table 2). As illustrated in Table 2, the fundamental activities of *ideating*, *realising*, and *critiquing*, experienced by pupils through project-based learning where they design, make and evaluate solutions in response to contexts and needs, are at the heart of D&T and are encapsulated in curricular frameworks around the world. These themes are evident throughout the excerpts in Table 2, where the attitudes and dispositions associated with 'designerly' and technological knowing (thinking, doing, and valuing) are fostered in versions of various national curricula. Therefore, project-based learning involving designing, making, and evaluating requires (and has) shared

understandings and practices (or signature pedagogies) of how best to teach it across the D&T education community (the so-called *deep* structures of the subject). Whilst this study focuses on the experiences and views of D&T educators in England, it has broader implications for and application to global 'Technology Education' curricula sharing the design-make-evaluate paradigm inherent to the NC in England.

Country	Purpose Statement Excerpts
Australia (ACARA, 2014)	"The practical nature of the Technologies learning area engages students in critical and creative thinking, including understanding interrelationships in systems when solving complex problems. **A systematic approach to experimentation, problem-solving, prototyping and evaluation instils in students the value of planning and reviewing processes to realise ideas**."
England (DfE, 2013)	"Design and technology is an inspiring, rigorous and practical subject. **Using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts, considering their own and others' needs, wants and values**... Pupils learn how to take risks, becoming resourceful, innovative, enterprising and capable citizens."
Hong Kong (EB, 2016)	"Technology Education (TE) is the study of the **purposeful application of knowledge…, skills and experiences in using resources to create or add value to products and systems to meet human needs**… TE subjects are introduced at different points of time with varying emphases to cope with the social, economic and technological development both locally and globally.
New Zealand (TKI, 2017)	"Technology is intervention by design. **It uses intellectual and practical resources to create technological outcomes, which expand human possibilities by addressing needs and realising opportunities**. Design is characterised by innovation and adaptation and is at the heart of technological practice. It is informed by critical and creative thinking and specific design processes."
South Africa (DoE, 2002)	"**Technology has existed throughout history as an activity in which people use a combination of knowledge, skills and available resources to develop solutions to meet their daily needs and wants**. Some of these solutions are in the form of products while some solutions involve a combination of products to make systems… However, the knowledge, skills and resources used today are different because of the accelerating developments in technology. Today's society is complex and diverse."
Sweden (Skolverket, 2018)	"Teaching in technology should aim at helping the pupils to develop their technical expertise and technical awareness so that they can orient themselves and act in a technologically intensive world...**Teaching should help pupils to develop their knowledge on how to solve different problems and satisfy needs with the use of technology. Pupils should also be given the preconditions to develop their own technical ideas and solutions**."
United States of America (ITEEA, 2021)	"In order to be a technologically literate citizen, a person should understand what technology is, how it works, how it shapes society and in turn how society shapes it. Moreover, **a technologically literate person has some abilities to "do" technology that enables them to use their inventiveness to design and build things and to solve practical problems that are technological in nature**."

Table 2 Global design and technology curricula [emphases mine]

As outlined in the excerpts above (Table 2), a common thread (or signature pedagogy) emerges across various curricula that emphasise learning through project-based learning. Whether the focus is on developing children and young people who are “technologically literate” (ITEEA, 2021), which is a key focus in the USA, or the more Eurocentric traditions where “pupils design and make products” (DfE, 2013), doing in the form of contextualised problem solving in response to needs is shared. Furthermore, where pupils are expected to create technological or technical solutions with some degree of autonomy, the need for effective instruction (including demonstration of procedural knowledge / skill) is paramount. Bring the discussion back to demonstration, this is an important facilitating teaching method (Petrina, 2007) for the teacher to model and explain the skills and procedural knowledge necessary for learners to participate in design-make-evaluate projects.

Shulman described signature pedagogies as being comprised of three structures (or layers): surface, deep, and implicit (Table 1). The surface structures are the teaching methods employed in the D&T classroom. These include a range of pedagogical approaches, from the demonstration of practical skills to the facilitation of creative and innovative problem-solving. Shulman’s description of “approaching and withdrawing” (Shulman, 2005, p. 54) implies a continuum from relatively restrictive approaches (narrowing learners’ focus onto specific tasks or procedures) to more expansive approaches (encouraging autonomy and creativity), such as generating innovative solutions in response to a design context and problem. Extending our analysis from the surface to the deep structures, the curricular frameworks cited in Table 2 emphasise ‘doing’ and project-based learning involving ideating, realising, and critiquing (albeit more commonly stated in terms of designing, making, and

evaluating). The three fundamental activities can be configured in various ways, one of which (a four-fold pedagogical model for D&T) will be outlined in Section 4. The implicit structure can be looked at from both a personal and a curricular perspective. Many different values are and can be ascribed to D&T, which can be influenced by who is doing the valuing and what the assumed purpose of the subject is. As discussed above, the origins of D&T are in craft and making, which have recently gained significant interest through television programmes in the UK such as *Handmade: Britain's Best Woodworker*, *The Great British Sewing Bee* and *The Great British Bake Off*. Similarly, there is a psychomotor argument for teaching practical skills, such as the declining dexterity of surgeons (Coughlan, 2018). However, it is arguable that a modern D&T curriculum should be modelled on the transformational nature of the subject, through ideation, realisation, and critique, rather than a craft or making centric paradigm. Arguments include the need for human creativity and innovation as artificial intelligence replaces many current technical roles (e.g. Bianzino, 2021; Schweisfurth, 2020) and the emergence of new technologies and related jobs, requiring so-called twenty-first century skills (OECD, 2018).

The literature on signature pedagogies is largely focused on higher education, with growing interest from both STEM and Humanities disciplines, with a few articles referring to subject teaching in schools. Two defining characteristics of signature pedagogies emerge from the literature; knowledge for action and uncertainty in learning (McLain, 2021c). Design projects are ideal spaces for skills (and procedural knowledge) to be applied in contexts where the outcomes are uncertain, i.e., the deep structure. This provides opportunities to develop resilience and autonomy, alongside creativity and innovation. The roles of learning environments and teachers

are also important features of signature pedagogies, with specialist facilities, resources, and expertise at the heart of how D&T is taught and learnt. Four further features that emerge from signature pedagogies for design education reinforce these notions:

- Design thinking (praxis, thinking/doing, capability, etc.)
- Design studio (learning environments, ways of working, etc.)
- Design 'crit' (critique, assessment, formative feedback, etc.)
- Design project (design and make, project-based learning, etc.)

The design project is a, if not 'the', deep structure of D&T, as the generally accepted 'best way' to develop the subject's body of knowledge (cf. Kimbell, 1994), including ways of knowing that are conceptual (drawing on abstract ideas), procedural (applying knowledge and processes – i.e., skills) and strategic (deliberate and autonomous) (McCormick, 1997; McLain et al., 2018, 2019a). The epistemological basis of D&T has been debated and questioned (e.g. DfE, 2011), but the changing nature of technology means that any technological body of knowledge will evolve and change over time. However, this is only problematic when considering the temporal nature of resources (materials and components) and tools (hand, machine, and computer-based), rather than knowledge of how these 'technologies' are used to solve problems and address the needs and wants of human beings, not to mention the wider realms of flora, fauna, the environment, and society.

In the recent review of GCSE (DfE, 2015a) and AS/A Level (DfE, 2015b) qualifications in England, the subject content documents attempted to define a body of knowledge that was not built on the material classifications that characterised the

previous syllabi, i.e., electronics, food, graphics, resistant materials, systems and control, and textiles. Technical principles covered the knowledge pupils need "to make effective design choices in relation to which materials, components and systems" (DfE, 2015a, p. 5), which included properties of materials and processes for realising them into prototypes. Design and making principles focused on how technical knowledge is used in action, including strategies for ideating, realising critiquing, communicating, and knowing (McLain, 2021b; McLain, in press). My research is unique in suggesting that demonstration is a relatively restrictive and teacher-led teaching method, appropriate for the teaching of skill and procedural knowledge (e.g., techniques for making when 'realising' or sketching when 'communicating' design ideas). It is one teaching method alongside a range of approaches (positioned along a restrictive-expansive continuum), with more expansive approaches including open-ended, and pupil-led approaches (e.g., brainstorming when 'ideating' of design fiction to develop empathetic ways of 'knowing').

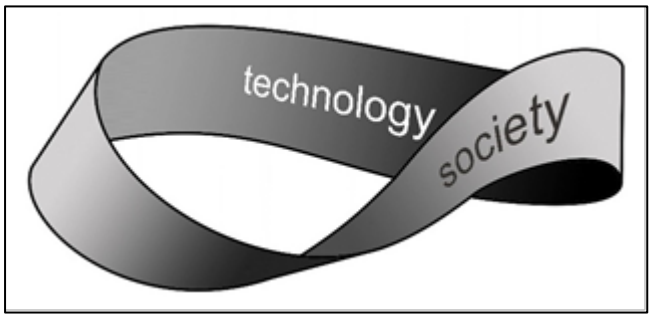

Figure 1 Dynamic Interaction of Technological and Social Activity (McLain et al., 2019a, p. 475)

3 Methodology

3.1 Philosophical Position

The research paradigm for this research is broadly qualitative and interpretive. The overarching methodological framework of the portfolio of papers is informed by constructivist grounded theory (Charmaz, 2006), adopted as an inductive approach, and aimed at exploring views and experiences as opposed to testing hypotheses. However, rather than beginning with a positioning statement, such as 'I am a qualitative researcher', I approach this research as a pragmatist in the tradition of Dewey (Dewey, 1966, 1944, 1916), as described by Biesta (2020). Pragmatism discourages rigid adherence to a particular lens or perspective and encourages the inquirer to start with a question and engage with problem finding. In brief, this means that: (a) I aim to gain knowledge in pursuit of desired ends, which is influenced by my values (axiology); (b) there is probably one reality, but individuals have their own interpretations (ontology); (c) theories of knowledge and relationships are determined by what I deem appropriate (epistemology); and (d) I do mixed-methods research (methodology). As a design and technology educator, pragmatism resonates with my professional education, which trained me to keep an open mind when exploring problems, deferring judgement, and considering different understandings and options before coming to a decision. This is somewhat akin to the concept of beginner's mind popularised by Shunryu Suzuki:

> *"The mind of the beginner is empty, free of the habits of the expert, ready to accept, to doubt, and open to all the possibilities."* (Suzuki, 1973, pp. 13-14)

Pragmatism is often associated with mixed-methods research (e.g., Biesta, 2010; Johnson & Onwuegbuzie, 2004) and is predicated on generating actionable and useable knowledge. Its rigour comes from its openness to different interpretations of data. In my research on educators' views of demonstration as an effective pedagogy, I have collected and analysed data from three different samples over a period, comparing responses and refining the research instrument. During this time, I have sought to interpret and understand the findings through the lenses of social constructivism and cognitive load theory (amongst others), which take fundamentally different philosophical positions. By doing this, I have aimed to address potential bias and developed a more nuanced interpretation of demonstration in D&T in the wider context of educational theories.

During the period of study, my position has oscillated between being an insider and an outsider researcher, working with fellow teacher educators (insider), teachers in schools (outsider) and preservice teachers (insider). However, having been a practicing D&T teacher, I was an insider who became an outsider. This potentially exposes my work to criticisms regarding bias and the validity of my research. Whilst my current *outsider* status potentially obscures my understanding of the impact of current policy within school contexts, it does afford me a more objective position from which to observe and critique practice (Kerstetter, 2012). As an insider within the field of teacher education, a potential limitation is a lack of objectivity due to being immersed in the community (Blaikie, 2007). To overcome this, and benefit from the insight if being immersed in the community, I have presented my findings at international conferences, debated with peers, and undergone peer-review for my journal articles. This pragmatic and ethically reflexive approach (Birch & Miller,

2012), described above, has helped me to address these concerns and attenuate bias, supported by testing emerging findings and analyses by presenting with peers at research conferences, stage-by-stage evaluation of data and discourse with critical friends (Costley, Elliott & Gibbs, 2010).

A relativist ontological stance was adopted concerning the nature of realities for individuals, which are multiple (Guba, 1981, 1990). Whilst positioning myself as Pragmatist, my early epistemological positionality was informed by social constructivism (e.g. Vygotsky, 1978), and the concept of tool mediation and social learning have continuted to influence my thinking. As a D&T educator, my axiological position is that practical and creative subjects play an important role in a broad and balanced school curriculum. Human activity is considered principally influenced by social and technological drives (Cole & Gajdamaschko, 2007; McLain et al., 2019a, 2019b; Vygotsky & Luria, 1930/1993) (Figure 1). Papers 5 and 6 (McLain et al., 2019a, 2019b) outline my theoretical position and framework, where I argue for the importance of D&T in the national and school curriculum. However, my critical perspective on D&T pedagogy is that an overreliance on restrictive teaching methods such as demonstration undermines the creative and innovative aims of the NC (DfE, 2013a). The purpose of these studies was to understand how D&T pedagogy is perceived and constructed by teachers, both pre- and in-service, and teacher educators. In turn, themes emerged that have potentially emancipatory power to deconstruct how the subject is taught and engage in transformative discourse.

3.2 Research Methodology

Papers 1 and 2 were pilot studies, the former using autoethnography and the latter, a mixed-methods questionnaire. The use of autoethnography in Paper 1 enabled me to reflect on over a decade of experience as a teacher of D&T working in secondary schools, at the beginning of my career as a university-based teacher educator and researcher. The use of a questionnaire in Paper 2 enabled me to gather data from 202 participants across several sites of study to gain insights into Key Stage 3 pupils' experiences in D&T. Papers 3, 4 and 7 used Q Methodology, a qualitative approach involving (a) participants ranking statements on the extent to which they agree with them and (b) their responses being interrogated using exploratory factor analysis to identify consensus between their subjective views (Watts & Stenner, 2012). Q Methodology (outlined below) is ideally suited to exploring subjective views and identifying shared perspectives, gaining an intersubjective understanding of the beliefs, values, and experiences of participants. Factor analysis is a statistical method for reducing numerous variables into a smaller number of groups (known as 'factors') identified by the degree of variance. In line with common practice in grounded theory research, the main literature review (Paper 8) was conducted at the end of the study, to facilitate the exploration of emergent themes and inform the summarising thesis (Glaser & Holton, 2007).

3.3 Research Methods

Papers 1 and 2 were pilot studies, primarily focusing on issues from my previous career as a teacher of D&T, relating to the tensions between the teaching of designing and making. As such, they were important problem finding activities, exploring the tensions between designing and making in D&T, before focusing on the demonstration as a signature pedagogy in D&T.

Paper 1 (McLain, 2012) utilised autoethnography (Spry, 2011), presenting personal and critical narrative of my experience of designing and making as a teacher of D&T. Autoethnographic approaches adopt a situated and embodied standpoint (Lave, 2009; Olesen, 2011) as an insider looking out at the world, making sense of past and present experiences. Autoethnographic writers make themselves accountable through reflexive self-examination of their context and factors influencing their actions and behaviours, focusing on stories and experience rather than making claims to 'truth'. This was my first peer-reviewed article, and it is included as part of the portfolio for this PhD by Published Work, as it situates me as an educator and researcher, recognising the tensions that I encountered and how they related to the history of D&T. The benefits of this research approach include its power to voice personal and minority lived experiences without making grand claims and developing theories. However, this opportunity to hear individual and subjective voices also reflects its limitations, and potential for bias and insularity.

Paper 2 (McLain et al., 2014) utilised a mixed-methods approach, with a questionnaire completed by a sample of 202 school children between the ages of 12 and 14 from five schools in North West England in 2012. The questionnaire consisted of seven quantitative questions, exploring the respondents' experience of D&T in their secondary school, with an opportunity for qualitative comments. The purpose of the questionnaire was to explore the children's awareness of how design skills were taught and to what extent they recognised pedagogical activities described in the National Strategies for the teaching of design subskills (DfES, 2004a). Semi-structured interviews were then conducted with teachers from the

schools to explore pupils' responses and teachers' perspectives. Questionnaires and interviews are useful ways to investigate subjective views, but the beliefs of participants do not necessarily align with their behaviours (Brinkmann & Kvale, 2018; Bryman, 2012). Therefore, themes from literature were used to triangulate findings, including Ofsted subject inspection reports.

3.3.1 Q Methodology

The main approach in this PhD by Published Work was Q Methodology, used in Papers 3 (McLain, 2018), 4 (McLain, 2021a) and 7 (McLain et al., 2021). Q Methodology (Brown, 1980) is a pragmatic research approach with its roots in the traditions of Dewey, Pierce and James (Watts & Stenner, 2012). It is ideally suited to exploring participants' subjective beliefs and values, making no grand claims of 'truth finding' but exploring consensus and distinguishing responses, identifying groups of participants with similar views. This was important in determining teachers' beliefs regarding their priorities and practice. A Q Methodological study begins with the creation of a set of statements describing a range of beliefs, perspectives, or opinions around a particular topic, known as a concourse. The concourse normally represents a wider range of views, which typically include polarising, opposing, or competing perspectives, and should attempt to include views from across the community or discipline being studied. These views are synthesised into a set of short statements, known as the Q-Set, each containing a discrete proposition. Participants are then invited to sort the statements on a continuum of most agree to most disagree. The subtle distinction between most agree/disagree and most/least agree is important, as is possible that participants either largely agree with all statements or vice versa.

The sorting process has two phases: (1) an initial sort into agree, disagree or neutral, followed by (2) a more nuanced placement of the statements along a continuum from most disagree to most agree. Sorting can be undertaken in-person, with the researcher present, or online using a tool like *QSortWare* (Pruneddu, 2014); however, Q Methodology experts tend to favour the in-person approach. In the second sorting phase, participants place the statements on a forced-choice frequency distribution (Figure 2), beginning with the (potentially) more polarising agree and disagree statements and filling in the remaining 'middle ground' with the neutral statements.

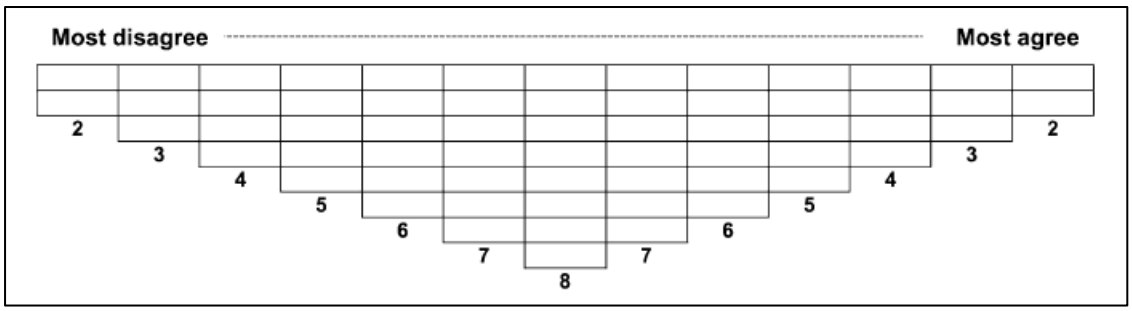

Figure 2 Forced-choice frequency distribution (McLain, 2018)

Where the research expects participant responses to be more polarised and contentious, the distribution frame is usually wider and shallower, allowing for more nuanced discrimination between statements. Conversely, where more consensus between participants' responses is expected, the frame can be made narrower and deeper. This means that the participant does not need to make meaningless or arbitrary decisions between two or more statements that they equally agree/disagree with. Whilst engaged with the sorting process, participants are encouraged to work in silence or independently to avoid influence from others, which may lead to them modifying their positioning of particular statements. Once the sort has been

completed, the participant may be asked to comment on any difficulties experienced with specific statements or any views that may have been missed in the concourse.

3.4 Ethics

All research has been conducted under the Liverpool John Moores University (LJMU) Code of Practice for research (LJMU, 2021) and British Educational Research Association (BERA) ethical guidelines (BERA, 2018). Permission has been obtained from co-authors to use the articles in my PhD by Published Work[10]. I was the lead researcher and author on all co-authored papers, and I collaborated with colleagues who provided feedback and support. Guba's criteria for assessing trustworthiness (Guba, 1981) have been used as guiding principles. The *credibility* of the findings for the Q Methodology papers (McLain, 2018, 2021a; McLain et al., 2021) that form the backbone of this PhD by Published Work comes from using three different sample groups, from whom information was gathered at different points in time. Similar themes emerging from the data reported in these papers indicate that the findings are likely to be *dependable* and *confirmable*. Also, the findings from the last of these studies (McLain et al., 2021) suggest that there are similar themes beyond D&T from the wider grouping of STEM educators.

3.4.1 Sampling

My research participants included 202 Key Stage 3 pupils in five secondary schools in North West England (Paper 2), alongside seven teachers (Paper 3) and 11 teacher educators (Paper 4) from across England and Scotland and 192 preservice teachers (Paper 7) in Merseyside. Six of the articles are open access and four are in high-ranking journals, as indicated by their 2020/21 Impact Factors (see Appendix 4:

[10] See Appendix 3.

Journal Profiles). My research on demonstration is being used by teacher educators in other universities and has been cited in peer-reviewed research. My research has also informed my work on curriculum design at a national level (Papers 9 and 10) and two chapters in edited books (Papers 11 and 12): Paper 11 is in a first edition and Paper 12 is a new chapter in a fourth edition.

Four of the papers in the portfolio entailed the collection of data from research participants. The sampling methods in each of these instances was non-probability (Guba, 1981; Lavrakas, 2008). Convenience sampling was used for Paper 2 (McLain et al., 2014), with survey responses from secondary age pupils (n=202) in five schools, gathered by D&T preservice teachers on placement. The sample (n=7) for Paper 3 (McLain, 2018) was purposive and comprised of schoolteachers in England, including school-based mentors for ITE students. Similarly, Paper 4's (McLain, 2021a) sample was also purposive, gathered from an online discussion group for D&T teacher educators (n=11) based in the UK. Student teachers (n=192) training to teaching in the secondary sector at LJMU in 2018/19, comprised the convenience sample for Paper 7 (McLain et al., 2021).

3.4.2 Participant Consent and Assent

Participant information was provided for participants in all four studies where data were gathered, and participants were able to make an informed choice on whether to participate. Where the participants were school pupils (Paper 2), the student teachers administering the questionnaires had the necessary enhanced Disclosure and Barring Service checks and safeguarding induction to teach in the schools. Furthermore, gatekeeper consent was obtained from the senior leadership in each school before the questionnaires were administered. Participant information was

provided for the classroom teachers and pupils, who completed assent forms alongside the questionnaires to indicate that they were aware of their choice to participate or not. Where data were gathered from adult participants, they completed an electronic (Papers 3 and 4) or hard-copy (Papers 2 and 7) consent form that was attached to their responses.

3.4.3 Data Protection

All physical data (Papers 2 and 7) were stored in a locked cupboard in a locked office at LJMU and electronic data (Papers 3 and 4) were stored on a secure, password-protected drive. Data were anonymised at the point of collection and coded for analysis, with personal information (i.e., name and contact details) stored separately to enhance confidentiality.

4 Findings and Discussion

In this section, I outline the findings from my portfolio for PhD by Published Work, focusing on the three Q Methodology studies views on demonstration and teacher modelling (Papers 3, 4 and 8) and the literature review of signature pedagogies. Papers 1 and 2 (outlined in Section 3.3) set the context and Papers 5 and 6 explore my positionality and the theoretical framework I was working within.

4.1 RQ1. What do D&T educators in the state secondary school sector, in England, perceive to be effective strategies for the 'demonstration' of skills?

In Paper 2 (McLain et al., 2014), pupils' responses to questions about the recognition of pedagogical activities promoting the teaching of design skills proved inconclusive. However, the responses to questions about their preferences for designing and making (supported by their qualitative comments) challenged the received wisdom prevalent amongst teachers at the time (e.g. Benson, 2017; Ofsted, 2008), that is,

that whilst most participants expressed a broad preference for making, designing was also popular. The context for this finding was the intractable problem that the teaching of making was more effective than designing in schools in England (Ofsted, 2002). The narrow range of pedagogical research in D&T, alongside an absence of instruction on how to teach design in preservice teacher preparation imply that common pedagogies (like demonstration) were not fully understood and potentially misapplied. This would also explain the apparent dominance of the demonstration in D&T lessons.

In response to the absence of literature for pre- and in-service teachers, I wrote a two-part article (McLain, Bell & Pratt, 2013, 2014) for a D&T teachers' magazine, exploring principles of demonstration. These articles were followed by three studies, presented at an international research conference, and published as peer-reviewed journal articles (McLain, 2018, 2021a; McLain et al., 2021) that form the empirical basis of this doctoral research.

4.1.1 Competent Management of the Learning Experience

The findings of the Q Methodology study in Paper 3 (McLain, 2018)[11] identified a single factor (group of participants with similar views) comprised of five of the seven participating teachers from England. The Q-Sort was undertaken online using *QSortWare* (Pruneddu, 2014) to enable data to be collected across a wider geographical area, with the respondents rank-ordering the 62 statements. The factor analysis was undertaken using specialist software, *PQMethod* (Schmolck, 2014) that is commonly used in Q Methodology research. The factor had an Eigenvalue (EV) of 1.51, indicating that it had a potential explanatory power: EVs greater than 1.00 are

[11] First published online on 1st September 2017.

significant in Q Methodology (Watts & Stenner, 2012). In line with Q Methodology practice, the factor was given an overarching title: *competent management of the learning experience*, encapsulating the characteristic features of the collective views expressed by the five participants.

The highest-ranked statements identified in this factor related to the teachers' competence (including safety and risk awareness) and clarity of explanation (including learning intentions and key points). Together with statements related to the importance of high standards and expectations, preparation, and whole-class awareness, this high ranking of competence and clarity indicated that this group viewed demonstration as a teacher-led activity, where the subject knowledge of the teacher is paramount. Mid-range statements ranked teacher questioning to probe pupils' understanding and recall knowledge as of moderate importance - relative to expertise in subject content and classroom management. The focus on questioning exploring prior knowledge from previous D&T units was greater than that on making links to learning from other subjects. However, despite a focus on teacher control, it was recognised that pupils should practice the skills being demonstrated before further teacher intervention or assistance. The overarching nature of this theme was the consolidation of learning, somewhat akin to the guided practice stage of DI (Adams & Engelmann, 1996; Hattie, 2008).

4.1.2 Expansive-Restrictive Continuum

Lower down on the participants' ranking were statements relating to pupils making their own choices and working autonomously. For example, the role of the teacher to identify alternative actions or enable pupils to do so for themselves was considered relatively unimportant. The use of questioning to encourage pupils to speculate or

think out loud was similarly ranked. The lower ranking of statements relating to pupils' choices and autonomy indicated a view that demonstration in D&T could be considered as a relatively narrow and teacher-led method, suited for developing skills (procedural knowledge of practical processes or techniques). The analysis of this finding drew on the concept of an expansive-restrictive framework (Fuller & Unwin, 2003), describing the range of approaches that the teacher can adopt to open up (expand) or narrow down (restrict) learning. The constructivist concept of scaffolding and fading have parallels to this (Bruner, 1960; Collins, Brown & Holum, 1991; Wood, Bruner & Ross, 1976).

This research implies that demonstration, as described in this study, is considered a relatively restrictive and teacher-centric teaching method. As such, it could be considered suitable for modelling and imitation, where pupils replicate a process demonstrated by the teacher. However, it would appear to be unsuited to more expansive and pupil-centric approaches, where the outcome is unclear, or pupils work in relative autonomy and make independent choices. Therefore, demonstration could be considered a form of teacher modelling and explaining, suited to more restrictive learning intentions in D&T, such as the correct use of tools and application of procedures.

4.1.3 Teacher as Expert Verses Teacher as Facilitator

Building on the first Q Methodology study presented in Paper 3 (McLain, 2018), Paper 4 (McLain, 2021a)[12] adopted the same research instrument and method, with a larger sample size (n=11). This time, the analysis identified two factors: Factor 1 comprised of six and Factor 2 comprised of four of the participating teachers (Note:

[12] First published online on 4th September 2019.

one participating teacher did not identify with the collective views of either of the two factors). The EVs were 3.60 for Factor 1 and 1.56 for Factor 2. In addition to identifying two groupings of participants expressing broadly similar views, the factor analysis software identified a subset of 30 statements showing consensus across both groups. The remaining 32 statements were identified as 'distinguishing', with less consensus between the two factors on how they were ranked. This latter set of statements provides an insight into the differences in how each group of participants viewed demonstration whilst undertaking the ranking exercise. The factors were given the titles:

- Factor 1: the teacher as *expert*
- Factor 2: the teacher as *facilitator*

The higher ranked statements for Factor 1 suggested a more *behaviourist* approach to demonstration and for Factor 2, more *constructivist*. For example, Factor 1 favoured clear explanations, the use of examples, sharing of learning outcomes, expectations and how to make progress. Factor 2, in contrast, emphasised the modelling and explaining of a whole process, with the use of information and communication technology to simulate or model processes, other adults in the classroom (e.g., a teaching assistant or technician) to support learners and modify their tone in response to the group and/or situation. Factor 1 also favoured a more *just-in-time* approach (McLain, 2018, 2021a, 2021b), where the complex processes are broken down into separate, linked demonstrations. This contrasted with Factor 2, which favoured a more *frontloaded* approach (McLain, 2018, 2021a, 2021b), where a whole process is modelled and/or explained in one demonstration. Factor 2 also

believed that modelling diagnostic processes, identifying alternative approaches, encouraging peer support and learners thinking aloud were relatively important.

4.1.4 Common Ground

Whilst Factors 1 and 2 are presented above as being broadly behaviourist or constructivist, both factors ranked the statement “the teacher identifies the main points or steps for the learners” and “the teacher gives an overview of the content of the skills or knowledge being demonstrated” (McLain, 2021a, pp. 17-18) in the top six for their group and “the teacher identifies hazards and risks for the learners” (p. 18) in the top ten. This emphasises a common core of PCK relating to the development of pupils’ D&T capability. Factor 2 tended towards a more constructivist and expansive approach than Factor 1, with statements relating to questioning not appearing in the top-ranked statements of the latter, although these did appear towards the top of the mid-range ranked responses. Factor 2 identified the use of questioning for recall and probing learners’ understanding, albeit at the lower end of the spectrum.

Although the respondents may have expressed more behaviourist or more constructivist leanings, the act of demonstration was broadly associated with statements that described more restrictive and teacher-led strategies, which aligns with the initial findings from Paper 3. This study implies that demonstration, in the way it is represented in the findings from Papers 3 and 4, is a relatively restrictive teaching method, ideally suited to the teaching of practical skills such as tool use and procedures. Furthermore, the way it has been represented in the literature supports this as a generalisable principle (cf. Banks, 2008; McLain, 2018; McLain, 2021a, 2021b; McLain et al., 2021; Petrina, 2007). In the context of D&T, demonstration

could be considered a form or a subset of teacher modelling, focusing on procedures more than concepts or processes. For example, a teacher might choose a more expansive approach to creative problem-solving by modelling a process rather than demonstrating how they might address a problem. The latter approach might limit pupils' creativity by unconsciously suggesting that there is one 'correct' solution, potentially limiting the pupils' creativity (e.g. Jeffrey & Craft, 2004; McLellan & Nicholl, 2011).

4.1.5 Alignment with the Views of Preservice STEM Teachers

Paper 7 (McLain et al., 2021) adapted a version of the instrument from Papers 3 and 4, utilising the reduced range of 32 'distinguishing' statements identified by the factor analysis in Paper 4 (McLain, 2021a). The reason is that these statements were more likely to lead to more polarised responses in the sorting activity. This study was conducted with 192 preservice secondary teachers in Merseyside (UK), early in the first semester of their one-year postgraduate ITE during the 2019/20 academic year. The Q-Sort activity was undertaken in classrooms at the end of a workshop, using physical cards that students arranged on a forced-choice frequency distribution chart (Figure 2) affixed to the chart at the end of the session. The sample did not include any D&T specialists, as the institution had no preservice teachers training in the subject that year.

The factor analysis of the responses identified seven factors. However, the discussion of findings in Paper 7 focused on the beliefs of preservice teachers of STEM subjects. Therefore, the two factors with strong representation (50%+) from STEM subjects were selected for interpretation. As with Paper 4, the factors were assigned titles:

- Factor 2: learning as a *continuum led* by the teacher
- Factor 5: learning as an *experience scaffolded* by the teacher

Like the analysis of responses in Paper 4, Factor 2 (n=14) represented a more *behaviourist* and Factor 5 (n=6) a more *constructivist* view of modelling and explaining. Interesting findings included the close alignment between views of STEM preservice teachers in this study and D&T teacher educators in Paper 4. Preservice teachers in subjects classified as practical (including art and design, dance, drama, music, physical education) held largely different views to those training to teach STEM subjects (biology, chemistry, computing, mathematics, physics) and, by extension, D&T. This suggested less congruence between so-called practical subjects, on the matter of modelling and explaining, than might have been expected. However, as with the two factors in Paper 4, common ground existed on the use of questioning, providing a running commentary, and circulating the room after a demonstration.

4.2 RQ2. How does a signature pedagogies framework enable exploration of D&T pedagogies to evaluate and select appropriate teaching methods?

At the end of this research, a systematic literature review was conducted (McLain, 2021c), in line with common practices in grounded theory research (Glaser & Holton, 2007). The aim is to start data collection without being hampered by preconceptions and undue influence, allowing theory to emerge from the data (p. 58). Paper 8 examined peer-reviewed research articles with the terms “signature pedagogy” or “signature pedagogies” in the title, abstract or key words. See Section 2.2 for an overview of signature pedagogies (Shulman, 2005).

A total of 21 articles exploring the original work of Lee Shulman across a variety of disciplines were identified in the British Education Index, a database that enables users to search British education journals, theses, etc. Of the articles identified, 11 met the inclusion criteria and were selected for the review. The articles were then coded using NVIVO (QSR, 2020) to identify and map emerging themes. This elicited four common themes relating to signature pedagogies, in general. The literature points out that signature pedagogies are not necessarily the same as effective pedagogies, but rather a collection of discipline-specific practices and approaches that go beyond individual institutions, recognised, and found throughout a sector.

One of the themes that emerged related to where signature pedagogies are located, in the physical (learning environment), embodied (educator) and conceptual (curriculum) sense. Whilst many learning environments in compulsory and post-compulsory education are generic classrooms, lecture theatres, etc., many disciplines require specialist spaces. These range from preservice teachers learning to teach in a school, to designers and engineers in studios or workshops. Specialist spaces include equipment and layouts optimised for experiential ways of knowing (Noel & Liub, 2017; Osmond & Tovey, 2015; Robinson, 2015). This reveals a tension between content knowledge and experiential learning in the curriculum, with signature pedagogies being more concerned with the latter. The role of the educator or teacher is also central to a discipline’s signature pedagogies. This is evident in the complexities of the master-apprentice relationship (Caldwell et al., 2016) and the collaboration between teacher and learner in modelling and dialogue (Love & Barrett, 2019; Noel & Liub, 2017), including the role of feedback.

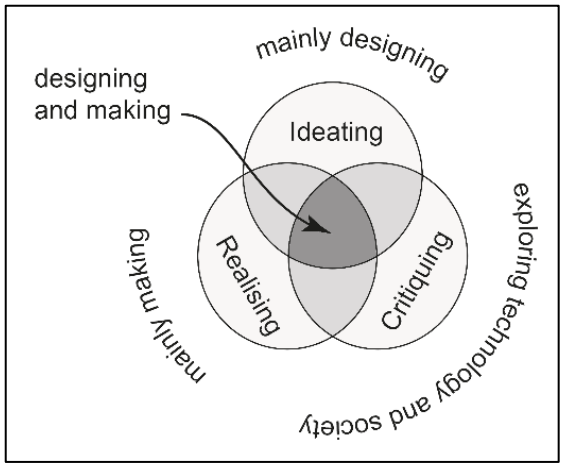

Figure 3 The four-fold pedagogical model for teaching D&T (McLain, in press)

4.3 Contribution to Knowledge

The findings from these studies make a significant contribution to the pedagogical knowledgebase for D&T education, specifically the act of 'demonstration'. Papers 3, 4 and 7 explored educators views, expressing a belief that subject competence and classroom management are paramount when effectively demonstrating skills. In turn, consolidation of learning and facilitation of independence were lower priorities. However, whilst demonstration was considered largely restrictive and teacher-led, the act of demonstration could be interpreted within both a constructivist and a behaviourist paradigm. Along this spectrum, demonstrations could be positioned as *frontloaded*, where a whole process is presented followed by the learners replicating it in guided practice; *just-in-time*, where the demonstration is staged with learners replicating in lockstep); and *after-failure*, where the teacher demonstrates (or re-demonstrates), having identified learners' misunderstandings or poor practice during guided practice.

Whilst demonstration is considered one of the most important teaching methods in D&T (McLain, 2018; Petrina, 2007), it has limitations. The findings of Papers 3, 4 and

7 indicate that it is ideally suited to the fundamental D&T activity of *realising*, where learners use tools and processes to model, prototype and make; in such cases, procedures and techniques are well defined and therefore more restrictive. However, the same findings suggest that it may be less suited to teaching the skills related to *ideating* and *critiquing*, which require more expansive pedagogical approaches (e.g. McLellan & Nicholl, 2011) and complete the design-make-evaluate D&T paradigm (Figure 3). As such, demonstration is best suited to the pedagogical approaches that foster realising, such as the 'mainly making' and 'designing and making' approaches (see Table 3 on page 50 for a description of the approaches, with benefits and limitations). This model has been adopted by the Design and Technology Association (D&TA) for the national D&T project resource bank (D&TA, 2019) and represents current pedagogy and good practice in the subject.

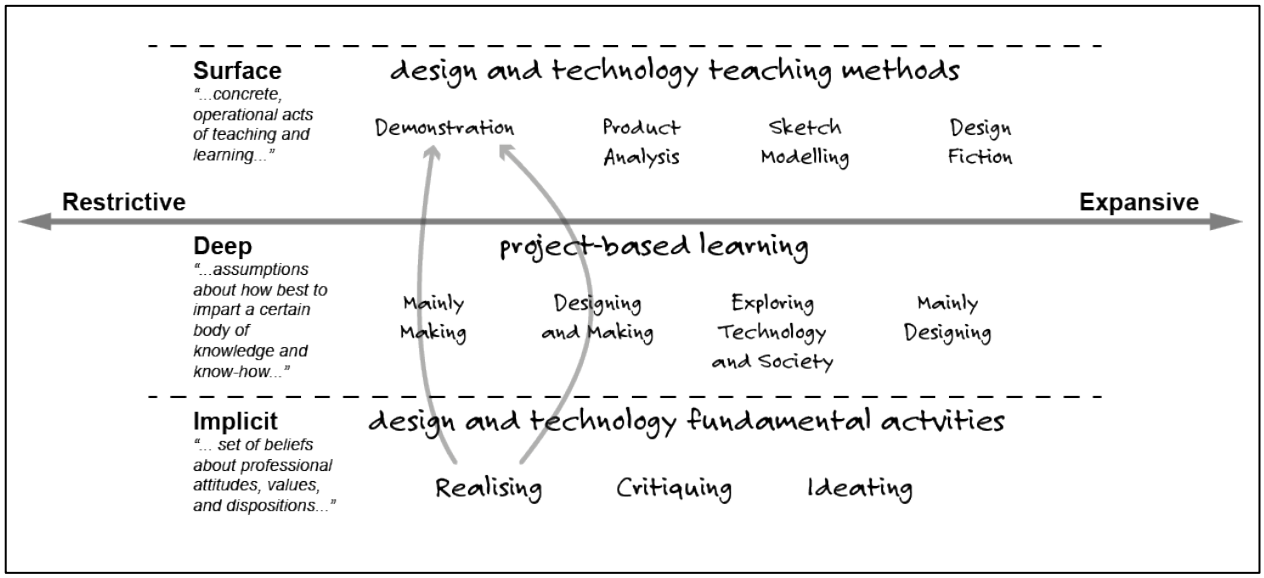

Figure 4 Signature pedagogies framework (adapted from McLain, in press)

The framework in Figure 4 was deduced from the signature pedagogy structures described in Table 1 (page 9), inserting the fundamental activities of ideating,

realising, and critiquing (analogous to designing, making and evaluating) representing the *implicit structure* of D&T (i.e., the attitudes, values and dispositions believed to be fostered by disciplinary learning). These are not necessarily the only attitudes, values and dispositions that apply to the subject, but are selected in this instance as being central the D&T curriculum in England. Similarly, project-based learning is identified as 'a' *deep structure* (i.e. commonly understood and practiced as the most effective way to teach the subject), which is broken down into the categories defined by the D&TA and in Table 3, below. For simplicity, four teaching methods are identified as *surface structures* (i.e., observable acts of teaching and learning), to illustrate a range of more restrictive (closed) and more expansive (open) approach. However, other teaching and learning methods could be added in order to facilitate professional dialogue regarding pedagogical intentions and choices. This framework helps to position and align demonstration (and other methods) with the learning intentions and approaches, recognising the degree of teacher control or pupil autonomy. This is important, as it helps the teacher to critically select and use appropriate approaches, understanding associated benefits and limitations.

The assumptions about the best way to impart D&T knowledge (the deep structure) is project-based learning, as evident in the D&TA's exemplar schemes of work (curriculum planning) for Key Stages 1 to 3 (2014, 2019), the GCSE (DfE, 2015a), and AS/A Level (DfE, 2015b) qualifications in England, and in the international research literature (e.g. Kokotsaki, Menzies & Wiggins, 2016; Xu et al., 2020). Combining the expansive-restrictive continuum adds breadth to the depth provided by Shulman's signature pedagogy structures. Identifying the surface structures (teaching methods) as either *more* expansive or *more* restrictive allows one to

explore the benefits and limitations of each approach (Table 3, page 50). Demonstration, as a relatively restrictive form of teacher modelling and explaining, is therefore ideally suited to *mainly making* and *designing and making* approaches, which in turn fosters *realising* activity, and the dispositions necessary for prototyping and producing design ideas.

5 Conclusions

This PhD by Published Works has explored secondary school D&T in-service teachers', D&T teacher educators' and STEM preservice teachers' beliefs and values concerning demonstration in the context of curriculum reform in England. It resulted in eight publications written between 2012 and 2021 that have systematically addressed a range of key issues and challenges in this under-researched and under-theorised area, which are summarised in the research objectives (see Section 1.2.2 Aims and Objectives, page 12). As such, it makes a significant contribution to the advancement of knowledge in the field of D&T education and to the discourse on pedagogical drives, approaches, and methods. The portfolio of peer-reviewed articles provides a coherent argument that demonstration is a *surface structure* in the signature pedagogy of D&T. It is a relatively restrictive method when considered along the expansive-restrictive continuum of pedagogical approaches, suited to teaching practical skills and procedural knowledge. It should, therefore, be used as part of a wider pedagogical repertoire that furthers the aims of the subject, as both a practical *and* a creative discipline. Demonstration is a form of teacher modelling ideally suited to *mainly making* and *designing and making* projects (Table 3), where the teacher is instructing learners techniques and procedures. Project-based learning is a *deep*

structure in D&T's signature pedagogy, informed by the fundamental activity of *realising* (Figure 3), an *implicit structure* underpinning D&T curriculum and pedagogy.

The portfolio of articles for this PhD by Published Work was drawn from my wider research and scholarship as a national leader in D&T education, with a growing international profile (see Appendix 1: Curriculum Vitae). My research has informed book chapters and webinars and is being used by fellow teacher educators and their student teachers. Half of the articles were sole-authored, and I was lead author for those co-authored, undertaking a significant proportion of the research and writing (see Appendix 3: Statements of Contribution from Co-Authors). The portfolio demonstrates my development as an independent and collaborative researcher, with four articles being accepted by high-ranking journals in the field (see Appendix 4: Journal Profiles).

5.1 Summary of Answers to the Research Questions

In response to **RQ1** (page 12), the findings from Papers 3, 4 and 7 revealed two pedagogical archetypes for D&T and STEM educators: the first a more behaviourist *teacher-as-expert* and the second a more constructivist *teacher-as-facilitator*. However, these two perspectives were not expressed as mutually exclusive, the differences being subtle and nuanced. The implications for this research suggest that teachers should consider demonstration as a surface structure (teaching method) at the restrictive end of an *expansive-restrictive continuum* of pedagogical approaches, with an understanding of its benefits and limitations as part of a broad pedagogical repertoire. Concerning **RQ2** (page 12), the findings from Paper 8 suggest that a signature pedagogy framework, incorporating an expansive-restrictive dimension,

could aid pre- and in-service teachers and teacher educators to engage in professional dialogue about the nature of D&T pedagogy, enabling them to critique contemporary models of pedagogy and make considered pedagogical choices that are congruent with the learning intentions underpinning curriculum design.

Approach	Description	Benefits	Limitations
Designing and making (DM)	Often referred to as *design, make and evaluate assignments (DMEA)*, this involved pupils following a design process from a set context, problem or brief. They involve ideating, realising and critiquing.	DM activities provide pupils with the opportunity to work with varying degrees of autonomy on a design project. They can be used to develop creativity, project management and resilience.	DM activities are limited by the time, resources, facilities and expertise available to pupils. Pupils may (and often do) come up with ideas that they are unable to realise. Furthermore, they do not have access to a wide range of different users and contexts.
Mainly designing (MD)	These activities focus on ideating activities but can involve limited realising or critiquing. They may involve modelling of prototypes, but typically not making using materials or components.	MD activities enable pupils to focus on the skills of designing creativity and innovation, without the constraints of having to make a prototype. Ideations can be speculative and address so-called wicked problems, using approaches like design fiction.	Designing without making limits opportunities for pupils to work creatively within constraints and realise their ideas using real materials and components. Unless pupils' creativity is fostered, and design skills are taught, they may struggle to be innovative.
Mainly making (MM)	These are similar to activities that have been described as *focused practical tasks (FPT)*. They are concerned with developing the skills related to making and involved realising activities.	MM activities enable pupils to develop skills and procedural knowledge, using tools and equipment to shape materials and components. The act of making is good for developing hand-eye coordination and wellbeing.	Working with real materials and components takes time and can potentially dominate the curriculum. Focusing on specific material areas and resources can also limit creativity and the consideration of alternative solutions to a problem.
Exploring technology and society (ETS)	There are some similarities to activities that have been labelled *investigate, disassemble, and evaluate activities (IDEA)*, but also embrace wider aspects of critiquing the impact of technology and society on each other.	ETS activities provide opportunities for learners to focus on the impact of technology and society, and the mediating role of design. A focus on critiquing enables pupils to explore issues and values, as well as simply analysing or evaluating products and systems.	Focusing on solely on issues of technology and society may inhibit designing and making activities, particularly where pupils are not supported to make decisions on next steps. An over emphasis on ETS activities could limit design and technology to a cerebral social science.

Table 3 Outline of the Four-fold Pedagogical Model for D&T (McLain, in press)

5.2 Limitations

These studies focused on educators' subjective views on demonstration as a signature pedagogy, with a particular emphasis on how D&T is taught in secondary schools. Although significant, two limitations must be borne in mind. The first is the potential for a disconnect between the participant responses, as presented in the studies, and their classroom practice. The second, that the relatively small sample in comparison to the wider population of educators in England potentially limits the strength of the argument for the theoretical position advanced through these studies. The findings from Papers 3, 4 and 7 present the subjective views of the participants. However, congruence with the wider body of literature is sufficient to confidently challenge how demonstration is viewed and used in D&T practice. These factors have implications for future research, as outlined in Section 5.4 Future Directions.

5.3 Implications

This research has implications for how demonstration and other teaching methods are introduced, discussed, and applied in ITE, both directly related to D&T teacher preparation and with a wider suite of STEM subjects. This could include opportunities for collaborative training for pre- and in-service teachers of STEM subjects. As such, it has relevance for teacher educators and their preservice teachers. The findings have influenced a recent chapter that I wrote for the fourth edition of *Learning to Teach D&T in the Secondary School* (McLain, 2021b) and the second edition of *Debates in D&T Education* (McLain, in press), both of which are key texts directly written for and marketed to preservice D&T teachers in England. Two of my papers on demonstration in D&T have recently been cited by leading researchers in the field of technology education research as examples of

“pedagogical approaches… growing in empirical support” (Buckley, Seery & Kimbell, 2022, p. 2). My research also influenced chapters in a new publication, *The Bloomsbury Handbook of Technology Education* (Gill et al., in press), an international edited book I am currently editing. The findings related to demonstration and signature pedagogies are also relevant for subject leaders in schools and policy makers for curriculum design and pedagogical practice.

5.4 Future Directions

The articles for this PhD by Published Work focused on educators’ views on effective demonstration as a form of teacher modelling, including pre- and in-service teachers and teacher educators. Further investigation evaluating the impact of this, and other teaching methods would enhance the theorisation and epistemological strength of the subject. Future investigation of demonstration in D&T could include the impact of frontloaded, just-in-time and after-failure approaches on pupils’ learning. Rigorous study of the wider signature pedagogies of D&T is also needed, with the framework described above providing a structure for professional dialogue on teaching methods and curriculum design. Research is needed to evaluate the impact on pupils’ learning through existing and emerging teaching practices in D&T. Possible future RQs that emerge from the findings and reflections on this research include:

- What impact do *frontloaded*, *just-in-time* and *after-failure* approaches to demonstration have on pupils’ capability in D&T?
- What are the features of effective demonstrations in D&T?
- What pedagogical approaches foster expansive learning in D&T?

This RQs would help to make the teaching of D&T in schools more evidence-informed and further strengthen the theoretical basis for the subject.

References

ACARA. (2014). The Australian Curriculum: Technologies Introduction. Retrieved from https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/introduction/

Adams, G., & Engelmann, S. (1996). *Research on Direct Instruction: 25 years beyond DISTAR*. Seattle: Educational Achievement Systems.

Atkinson, S. (1990). Design and Technology in the United Kingdom. *Journal of Technology Education, 2*(1). Retrieved from https://scholar.lib.vt.edu/ejournals/JTE/v2n1/html/atkinson.html

Atkinson, S. (in press). Design and Technology Education in England. In D. Gill, D. Irving-Bell, M. McLain, & D. Wooff (Eds.), *The Bloomsbury Handbook of Technology Education* London: Bloomsbury Publishing PLC.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(1), 417–423. https://doi.org/10.1016/S1364-6613(00)01538-2

Bandura, A. (1977). *Social learning theory*. New Jersey: Prentice Hall.

Banks, F. (2008). Teaching design and technology. In G. Owen-Jackson (Ed.), *Learning to teach design and technology in the secondary school: a companion to school experience* (2 ed., pp. 174-193). Abingdon, UK: Routledge.

Benson, C. (2017). Setting the context: design and technology and creativity. In C. Benson & S. Lawson (Eds.), *Teaching Design and Technology Creatively*. Abingdon, UK: Routledge.

BERA. (2018). *Ethical Guidelines for Educational Research* (4 ed.). Retrieved from https://www.bera.ac.uk/publication/ethical-guidelines-for-educational-research-2018

Bianzino, N. M. (2021). Is AI the start of the truly creative human?Is AI the start of the truly creative human? Retrieved from https://www.ey.com/en_gl/ai/is-ai-the-start-of-the-truly-creative-human

Biesta, G. (2010). Pragmatism and the philosophical foundations of mixed methods research. In A.Tashakkori & C. Teddlie (Eds), *SAGE Handbook of Mixed Methods in Social & Behavioural Sciences* (2 ed.). Thousand Oaks, CA: SAGE Publications Ltd.

Biesta, G. (2014). Pragmatising the curriculum: bringing knowledge back into the curriculum conversation, but via pragmatism. *The Curriculum Journal, 25*(1), 29-49. https://doi.org/10.1080/09585176.2013.874954

Biesta, G. (2020). *Educational Research: An Unorthodox Introduction*. London: Bloomsbury Academic.

Birch, M., & Miller, T. (2012). Encouraging participation: ethics and responsibilities. In T. Miller, M. Birch, & M. Mauthner (Eds.), *Ethics in qualitative research* (2nd ed.). London: SAGE Publications Ltd. pp. 94-107. https://dx.doi.org/10.4135/9781473913912.n7

Black, P. J., & Harrison, G. (1985). *In place of confusion: technology and science in the school curriculum: a discussion paper*: Nuffield-Chelsea Curriculum Trust and the National Centre for School Technology, Trent Polytechnic, UK.

Blaikie, N. (2007). *Approaches to Social Enquiry: Advancing Knowledge* (2nd ed.). Cambridge: Polity Press,.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals - Handbook 1, cognitive domain* New York: Longman Higher Education.

Boling, E., Siegel, M. A., Smith, K. M., & Parrish, P. (2013). Student goes on a journey; stranger rides into the classroom: Narratives and the instructor in the design studio. *Art, Design & Communication in Higher Education, 12*(2), 179–194. https://doi.org/10.1386/adch.12.2.179_1

Brinkmann, S., & Kvale, S. (2018). *Doing interviews* (2 ed.). London: SAGE Publications Ltd.

Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick: the science of successful learning*. Cambridge, MA: Harvard University Press.

Brown, S. R. (1980). *Political subjectivity: Applications of Q methodology in political science*. New Haven, USA: Yale University Press.

Bruner, J. S. (1960). *The Process of Education*. London: Harvard University Press.

Bryman, A. (2012). *Social Research Methods* (4 ed.). Oxford: Oxford University Press.

Buckley, J., Seery, N., & Kimbell, R. (2022). A Review of the Valid Methodological Use of Adaptive Comparative Judgment in Technology Education Research. *Frontiers in Education: Assessment, Testing and Applied Measurement, 7*(787926). https://doi.org/10.3389/feduc.2022.787926

Caldwell, G. A., Osborne, L., Mewburn, I., & Nottingham, A. (2016). Connecting the space between design and research: Explorations in participatory research supervision. *Educational Philosophy and Theory, 48*(13), 1352–1367. https://doi.org/10.1080/00131857.2015.1111129

Charmaz, K. (2006). Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis. In. London: SAGE.

Claxton, G., Lucas, B., & Webster, R. (2010). *Bodies of knowledge: how the learning sciences could transform practical and vocational education*. Retrieved from London:

Cole, M., & Gajdamaschko, N. (2007). *Vygotsky and culture*: Cambridge University Press.

Collins, A., Brown, J. S., & Holum, A. (1991). Cognitive apprenticeship: Making thinking visible. *American Educator, 15*(3), 38–46.

Costley, C., Elliott, G., & Gibbs, P. (2010). *Doing work based research: Approaches to enquiry for insider-researchers*. London: SAGE Publications Ltd. https://dx.doi.org/10.4135/9781446287880

Coughlan, S. (2018). Surgery students 'losing dexterity to stitch patients'. *BBC News*. Retrieved from https://www.bbc.co.uk/news/education-46019429

D&TA (2014). *Projects on a Page Scheme of Work*. Retrieved from https://www.data.org.uk/membership/member-benefits-outlined/projects-on-a-page-scheme-of-work/

D&TA (2019). *D&T Key Resources: a bank of teaching resources for key stage 3*. Retrieved from https://www.data.org.uk/media/3249/ks3-dt-project-bank-2019.pdf

Daniels, H. (2005). *An introduction to Vygotsky*: Psychology Press.

Dave, R. (1967). *Psychomotor domain*. Berlin: International Conference of Educational Testing.

DES/WO (1989). *Design and Technology for Ages 5 to 16: Proposals of the Secretary of State for Education and Science and the Secretary of State for Wales*. London: HMSO

DES/WO (1990). *Technology in the National Curriculum*. London

Dewey, J. (1966, 1944, 1916). *Democracy and education : an introduction to the philosophy of education*. London: Collier-Macmillan.

DfE (1995). *Design and Technology in the National Curriculum*. London: Department for Education

DfE (2011). *The Framework for the National Curriculum: A report by the Expert Panel for the National Curriculum review*. (DFE-00135-2011). London: Department for Education Retrieved from https://www.gov.uk/government/publications/framework-for-the-national-curriculum-a-report-by-the-expert-panel-for-the-national-curriculum-review

DfE (2013a). *National curriculum in England: framework for key stages 1 to 4*. London: Department for Education Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4

DfE (2013b). National curriculum: the national curriculum for England to be taught in all local-authority-maintained schools. Retrieved from https://www.gov.uk/government/collections/national-curriculum

DfE (2015a). *Design and technology GCSE subject content*. (DFE-00283-2015). Retrieved from https://www.gov.uk/government/publications/gcse-design-and-technology

DfE (2015b). *GCE AS and A level subject content for design and technology*. London Retrieved from https://www.gov.uk/government/publications/gce-as-and-a-level-design-and-technology

DfES (2004a). *Module 4: Teaching the subskills of designing*. (0971-2004 G). Retrieved from https://webarchive.nationalarchives.gov.uk/20081231051338/http://www.standards.dfes.gov.uk/secondary/keystage3/respub/design/downloads/

DfES (2004b). *Pedagogy and practice: Teaching and learning in secondary schools - Unit 6: Modelling*. In (Vol. DfES 0429-2004 G). Norwick, UK: HMSO.

DfES (2004c). *Pedagogy and practice: Teaching and learning in secondary schools - Unit 8: Explaining*. In. Norwick, UK: HMSO.

DoE (2002). *Revised National Curriculum Statement Grades R-9 (Schools)*. Pretoria: Department of Education of South Africa Retrieved from https://www.gov.za/sites/default/files/gcis_document/201409/natcur0.pdf

EB (2016). *Curriculum development > Key Learning Areas > Technology Education*. Retrieved from https://www.edb.gov.hk/en/curriculum-development/kla/technology-edu/index.html

EEF (2021). *Cognitive science approaches in the classroom: report summarising the evidence for cognitive science approaches in school settings*. Retrieved from https://educationendowmentfoundation.org.uk/education-evidence/evidence-reviews/cognitive-science-approaches-in-the-classroom

Fuller, A., & Unwin, L. (2003). *Learning as Apprentices in the Contemporary UK Workplace: creating and managing expansive and restrictive participation*, 16(4), 407-426. https://doi.org/10.1080/1363908032000093012

Gill, D., Irving-Bell, D., McLain, M., & Wooff, D. (Eds.). (in press). *The Bloomsbury Handbook of Technology Education: Perspectives and Practice*. London: Bloomsbury Publishing.

Glaser, B. G., & Holton, J. (2007). Remodeling Grounded Theory. *Historical Social Research / Historische Sozialforschung*, 47-68. Retrieved from http://www.jstor.org/stable/40981068

Guba, E. G. (1981). Criteria for Assessing the Trustworthiness of Naturalistic Inquiries. *EducationalCommunicationandTechnology, 29*(2), 17. Retrieved from http://www.jstor.org/stable/30219811

Guba, E. G. (1990). The Alternative Paradigm Dialogue. In E. G. Guba (Ed.), *The Paradigm Dialogue*. London: SAGE.

Hall, C., & Thomson, P. (2017). Creativity in teaching: What can teachers learn from artists? *Research Papers in Education, 32*(1), 106–120. https://doi.org/10.1080/02671522.2016.1144216

Harris, M., & Wilson, V. (2003). *Designs on the Curriculum? A review of the literature on the impact of Design and Technology in schools in England*. Retrieved from https://webarchive.nationalarchives.gov.uk/20090204141420/http://www.dcsf.gov.uk/research/data/uploadfiles/RR401.pdf [accessed 28/03/2022]

Harrow, A. J. (1972). *A taxonomy of the psychomotor domain*. New York: David McKay Company.

Hattie, J. (2008). *Visible Learning: a synthesis of over 800 meta-analyses relating to achievement*. Abingdon, UK: Routledge.

ITEEA. (2021). *Technologically Literate Citizens*. Retrieved from https://www.iteea.org/48897.aspx [accessed 28/03/2022]

Jeffrey, B., & Craft, A. (2004). Teaching creatively and teaching for creativity: distinctions and relationships. *Educational Studies, 30*(1), 77-87. https://doi.org/10.1080/0305569032000159750

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, 33(7), 14–26. https://doi.org/10.3102/0013189X033007014

Kerstetter, K. (2012). Insider, Outsider, or Somewhere Between: The Impact of Researchers' Identities on the Community-Based Research Process. *Journal of Rural Social Sciences*, 27(2). https://egrove.olemiss.edu/jrss/vol27/iss2/7

Kimbell, R. (1994). Tasks in Technology: An Analysis of Their Purposes and Effects. *International Journal of Technology and Design Education, 4*(3), 241-255.

Kimbell, R., Bain, J., Miller, S., Stables, K., Wheeler, T., & Wright, R. (2004). *Assessing Design Innovation: a research & development project for the Department for Education & Skills (DfES) and the Qualifications and Curriculum Authority (QCA).* . Retrieved from http://research.gold.ac.uk/id/eprint/280

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. *Educational Psychologist, 41*(2), 75-86. https://doi.org/10.1207/s15326985ep4102_1

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267-277. https://doi.org/10.1177%2F1365480216659733

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). *Taxonomy of educational objectives: Handbook II: Affective domain*. New York: David McKay Company.

Lave, J. (2009). The Practice of Learning. In K. Illieris (Ed.), *Contemporary Theories of Learning: Learning Theorists ... In Their Own Words*. Abingdon, UK: Routledge.

Lavrakas, P. J. (2008, 2021/12/01). Purposive Sample. *Encyclopedia of Survey Research Methods.* Retrieved from

https://methods.sagepub.com/reference/encyclopedia-of-survey-research-methods

Lewicki, P., Czyzewska, M., & Hoffman, H. (1987). Unconscious acquisition of complex procedural knowledge. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 13(4), 523–530. https://doi.org/10.1037/0278-7393.13.4.523

LJMU. (2021). Research Ethics and Governance. Retrieved from https://www.ljmu.ac.uk/ris/research-ethics-and-governance

Long, R., & Danechi, S. (2019). *Commons Research Briefing: English Baccalaureate*. UK Parliament Retrieved from https://commonslibrary.parliament.uk/research-briefings/sn06045/

Love, K. G., & Barrett, M. S. (2019). Signature pedagogies for musical practice: A case study of creativity development in an orchestral composers' workshop. *Psychology of Music, 47*(1), 551–567. https://doi.org/10.1177%2F0305735618765317

Marranzo, R. J., & Kendell, J. S. (2007). *The new taxonomy of educational objectives*. London: SAGE.

Martin, A. J. (2016). Using Load Reduction Instruction (LRI) to boost motivation and engagement. In (The 35th Annual Vernon Wall Lecture ed.). Leicester, UK: British Psychological Society.

McCormick, R. (1997). Conceptual and Procedural Knowledge. *International Journal of Technology and Design Education, 7*(1), 141-159. https://doi.org/10.1023/A:1008819912213

McLain, M. (2012). An (auto)Ethnographic Narrative of the Teaching of Designing within Design and Technology in the English Curriculum. *Procedia - Social and Behavioral Sciences, 45*, 318-330. https://doi.org/10.1016/j.sbspro.2012.06.568

McLain, M. (2016). *Teacher educator perspectives on pedagogical modelling and explaining in Design and Technology: a Q Methodology Study.* Paper presented at the PATT32 Conference, Technology Education for 21st Century Skills, 23-26 August, Delft University of Technology and HU University of Applied Sciences.

McLain, M. (2018). Emerging perspectives on the demonstration as a signature pedagogy in design and technology education. *International Journal of*

Technology and Design Education, 28(4), 985-1000. https://doi.org/10.1007/s10798-017-9425-0McLain, M. (2021a). Developing perspectives on the demonstration as a signature pedagogy in design and technology. *International Journal of Technology and Design Education, 31*(1), 3-26. https://doi.org/10.1007/s10798-019-09545-1

McLain, M. (2021b). Key pedagogies in design and technology. In A. Hardy (Ed.), *Learning to teach design and technology in the secondary school: a companion to the school experience* (4 ed.). Abingdon, UK: Routledge.

McLain, M. (2021c). Towards a signature pedagogy for design and technology education: a literature review. *International Journal of Technology and Design Education, Online First*. https://doi.org/10.1007/s10798-021-09667-5

McLain, M. (in press). What's so special about design and technology anyway? Exploring contemporary and future teaching using a signature pedagogies discursive framework. In A. Hardy (Ed.), *Debates in Design and Technology Education* (2 ed.). Abingdon, UK: Routledge.

McLain, M., Barlex, D., Bell, D., & Hardy, A. (2015). *Teacher perspectives on pedagogical modelling and explaining in Design and Technology: a Q Methodology Study.* Paper presented at the PATT 29 Conference, Plurality and Complementarity of Approaches in Design & Technology Education, 6-10 April, Marseille Université.

McLain, M., Bell, D., & Pratt, A. (2013). Show-how know-how (Part 1): Theory and practice for demonstrating in Design and Technology. *D&T Practice, 2013(3)*.

McLain, M., Bell, D., & Pratt, A. (2014). Show-how know-how (Part 2): Theory and practice for demonstrating in Design and Technology. *D&T Practice, 2014(1)*.

McLain, M., Bell, D., Smith, J., & Martin, M. (2014). Reviewing the Impact of the National Strategies Design and Technology Framework for Key Stage Three *The European Journal of Social and Behavioural Sciences, IX*(2), 12. http://dx.doi.org/10.15405/ejsbs.119

McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2018). *Cultural and historical roots for design and technology education: why technology makes us human*. Paper presented at the PATT36 Research and Practice in Technology Education: Perspectives on Human Capacity and Development, Athlone Institute of Technology, Co. Westmeath, Ireland. http://terg.ie/index.php/patt36-proceedings/

McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2019a). How technology makes us human: cultural and historical roots for design and technology education. *Curriculum Journal,* 30(4), 464-483. https://doi.org/10.1080/09585176.2019.1649163

McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2019b). Humanising the design and technology curriculum: why technology education makes us human. *Design and Technology Education: An International Journal*, 24(2), 8-19. https://ojs.lboro.ac.uk/DATE/article/view/2610

McLain, M., McLain, D., Wooff, D., & Irving-Bell, D. (2021). Preservice Teachers' Perspectives on Modelling and Explaining in STEM Subjects: a Q Methodology Study. *Techne: Research in in Sloyd Education and Crafts Science, 28*(2), 367–374. Retrieved from https://journals.oslomet.no/index.php/techneA/article/view/4292

McLellan, R., & Nicholl, B. (2011). "If I was going to design a chair, the last thing I would look at is a chair": product analysis and the causes of fixation in students' design work 11–16 years. *International Journal of Technology and Design Education, 21*(1), 71-92. https://doi.org/10.1007/s10798-009-9107-7

Mincu, M. E. (2015). Teacher quality and school improvement: What is the role of research? *Oxford Review of Education, 41*(2), 253–269. https://doi.org/10.1080/03054985.2015.1023013

Muller, J., & Young, M. (2019). Knowledge, power and powerful knowledge re-visited. *The Curriculum Journal, 30*(2), 196-214. doi:10.1080/09585176.2019.1570292

Murphy, P. (2008). Defining Pedagogy. In K. Hall, P. Murphy, & J. Soler (Eds.), *Pedagogy and practice: culture and identities* (pp. 28-39). London: SAGE Publicatiosn Ltd.

Noel, L., & Liub, T. (2017). Using design thinking to create a new education paradigm for elementary level children for higher student engagement and success. *Design and Technology Education: An International Journal, 22*(1). Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2198

OECD. (2018). *The Future of Education and Skills: Education 2030*. Retrieved from Paris: https://www.oecd.org/education/2030-project/contact/E2030_Position_Paper_(05.04.2018).pdf

Ofsted. (2002). *Secondary Subject Reports 2000/01: Design and technology*. Retrieved from London:

Ofsted. (2008). *Education for a technologically advanced nation: design and technology in schools 2004–07*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/413704/Meeting_technological_challenges.doc

Olesen, V. (2011). In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 129-146). London: SAGE Publications Ltd.

Osmond, J., & Tovey, M. (2015). The threshold of uncertainty in teaching design. *Design and Technology Education: An International Journal, 20*(2), 50-57. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2042

Peel, D. (2011). Signature pedagogies and the built environment. *Journal for Education in the Built Environment, 6*(2), 1–7. https://doi.org/10.11120/jebe.2011.06020001

Petrina, S. (2007). *Advanced Teaching Methods for the Technology Classroom*. London: Information Science Publishing.

Pruneddu, A. (2014). QSortWare. Retrieved from http://www.qsortouch.com

QCA. (2004). *Design and technology: The National Curriculum for England: Key stages 1–4*. London: Department for Education and Skills / Qualifications and Curriculum Authority

QCA. (2007). *Design and technology: Programme of study for key stage 3 and attainment target*. London: Qualifi cations and Curriculum Authority

QSR. (2020). NVivo (Version 12). Chadstone: QSR International. Retrieved from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Robinson, J. M. (2015). Teaching religion around the world: A modest first glimpse. *Teaching Theology & Religion, 18*(3), 235–247. https://doi.org/10.1111/teth.12290

Rowe, K. (2006). Effective teaching practices for students with and without learning difficulties: Constructivism as a legitimate theory of learning AND of teaching? In (pp. 1-24): Austrailian Council for Educational Research.

Rutland, M., & Spendlove, D. (2007). Creativity in design & technology. In D. Barlex (Ed.), *Design and Technology for the Next Generation*. Whitchurch, UK: Cliffco Communications.

Ryle, G. (2000, 1949). *The concept of mind* (New Edition ed.). London: Penguin Classics.

Schmolck, P. (2014). *PQMethod* (Version 2.35). Retrieved from http://schmolck.userweb.mwn.de/qmethod/index.htm

Schweisfurth, T. (2020). Can AI ever rival human creativity? Here's what the science says. Retrieved from https://www.fastcompany.com/90460778/can-ai-ever-rival-human-creativity-heres-what-the-science-says

Sennett, R. (2008). *The Craftsman*. London: Penguin Books Ltd.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*(2), 4-14. Retrieved from http://www.jstor.org/stable/1175860

Shulman, L. S. (2005). Signature Pedagogies in the Professions. *Daedalus, 134*(3), 52-59. https://doi.org/10.1162/0011526054622015

Simpson, E. J. (1972). *The classification of educational objectives in the psychomotor domain*. Washington: Gryphon House.

Skolverket. (2018). *Curriculum for the compulsory school, preschool class and school-age educare*. Retrieved from https://www.skolverket.se/download/18.31c292d516e7445866a218f/1576654682907/pdf3984.pdf

Spry, T. (2011). Performative Autoethnography: critical embodiments and possibilities. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage Handbook of Qualitative Research* (pp. 497-511). London: SAGE Publications Ltd.

Stables, K. (2020). Signature pedagogies for designing: A speculative framework for supporting learningand teaching in design and technology education. In P. J. Williams & D. Barlex (Eds.), *Pedagogy fortechnology education in secondary schools: Research informed perspectives for classroom teachers*. Springer Nature Switzerland.

Suzuki, S. (1973). *Zen Mind, Beginner's Mind*. New York: Weatherhill, Inc.

Tappan, M. B. (1997). Language, culture, and moral development: A Vygotskian perspective. *Developmental Review of Research in Education, 17*(1), 78–100. https://doi.org/10.1006/drev.1996.0422

TKI. (2017). The New Zealand Curriculum Online: Technology. Retrieved from https://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Technology

Vygotsky, L. S. (1978). *Mind in society: the development of higher psychological processes*. London: Harvard University Press.

Vygotsky, L. S., & Luria, A. R. (1930/1993). *Studies on the history of behavior: Ape, primitive, and child*. Hillsdale, USA: Erlbaum.

Watts, S., & Stenner, P. (2012). *Doing Q Methodological Research: Theory, Method & Interpretation*. London: SAGE.

White, J. (2018). The weakness of 'powerful knowledge'. *London Review of Education, 16*(2), 11. https://doi.org/10.18546/LRE.16.2.11

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Child Psychology & Psychiatry & Allied Disciplines, 17*(2), 89-100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x

Xu, M., Williams, P. J., Gu, J., & Zhang, H. (2020). Hotspots and trends of technology education in the International Journal of Technology and Design Education: 2000–2018. *International Journal of Technology and Design Education, 30*(2), 207-224. https://doi.org/10.1007/s10798-019-09508-6