Examining the Potential Impact of Digital Game Making in Curricula Based Teaching: Initial Observations

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Declarations of interest: none

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 645215 and forms part of the No One Left Behind project.

Abstract: Digital game making is becoming an increasingly common means of learning in schools due to the appeal of delivering curriculum-based learning objectives while tapping into the popularity of videogames. Indeed, research suggests that digital game making may improve cognitive and behavioral skills in learners and this may have significant impact on learners with special education needs and disabilities (SEND). However, past work in digital game making has limited involvement with learners with SEND, focuses on short-term evaluations and is utilised during extra-curricular sessions with few studies using an action-based field research approach. Furthermore, there is little quantitative data from defined methodologies that demonstrate the impact of digital game-making on learning. This paper presents results from two field trials examining the use of digital game making in two schools (one mixed ability primary and one special school) to deliver national curriculum-based content over 8-weeks. Results from a feasibility trial informed a pedagogical design and identified evaluation metrics for a subsequent longer trial. Evaluation metrics included learner engagement and collaboration with peers as suitable indicators of inclusive learning. Impact on these metrics was measured using an in-class observation tool that sampled learner behavior yielding quantitative data and follow up interviews with teachers yielding qualitative data. Results suggest that digital game making is at least as effective in encouraging engagement and collaboration in learners when compared to traditional methods, with it being more engaging for learners with special needs. Contributions from this paper provide quantifiable evidence for the perceived benefits of using digital game making and a methodology for evaluating engagement and collaboration through classroom observation. Recommendations for further work and refinements of the pedagogical implementation that builds on these findings are presented.

Keywords: Digital Game Making, Special Education, Engagement, Collaboration, Primary Education

1. Introduction

Education has long sought to tap into the mass appeal of games to promote student learning. Digital games are now an integral part of children's lives and should be utilised in schools as well (Gabriel, 2018). Digital game making can also benefit learners, by allowing them to create something that teaches them content and literacy in a meaningful way (Kafei and Burke, 2016). As pointed out by Gilbert (2007), students now live in a technology rich society that requires adaptations to pedagogy and curriculum where knowledge is developed through a process and learning involves generating new knowledge. However, there are barriers to access to utilising digital game making. For example, it requires a degree of programming skill that would prevent some learners from being able to generate content, particularly learners with SEND. As such, given the suggestion that digital game making can be powerful tool for learning, this research asks what does digital game making offer, how could it be implemented within a classroom composed of learners with a wide variety of needs and abilities, and what kind of impact could it have within such a complex setting?

While not game making, Game Based Learning (GBL) is already commonplace and suggests the area as a whole can be effective in engaging learners. Within primary education it has been implemented across a wide range of subject areas to achieve a number of learning outcomes (Hainey et al. 2016). Within wider teaching and learning, playing games can impact learner engagement, cognitive ability and acquisition of knowledge content (Brown et al., 2011; Connelly et al., 2012; Foster, 2008). Games have the potential to simulate real world complexity and make learning more connected to what students would expect to find outside of the classroom setting (Spires et al., 2011). Furthermore, video games can be used as therapeutic treatments for students with autism spectrum disorder (Malinverni et al. 2016) and potentially be effective in engaging learners with special education needs due, in part, to games being ubiquitous to children's leisure environment (Griffiths, 2002). Indeed, Buckland et al. (2013) found that serious games provide a positive learning experience and can be an effective means of studying subject material. Researchers point out however, that what is absent in discussions concerning the effectiveness of serious gaming is the inclusion of constructionist gaming approaches, where games are designed by students themselves for learning benefits (Kafai and Burke, 2015).

Digital game making could add to the aforementioned benefits of GBL and serious games by also generating knowledge through the creation of the game itself. Utilisation of digital game making platforms is an increasingly viable option for teachers due to the increased popularity of visual programming languages such as Scratch (Resnick et al., 2009) and Pocket Code (Slany, 2014). A number of studies have demonstrated that the use of such platforms can “engage the disengaged” with learning (Thumlert et al., 2018). However, few studies have focussed on the creation of an inclusive environment composed of complex, large sized cohorts found in most modern classrooms. Furthermore, only a few studies have focussed on deploying digital game making to tackle learning for students with special educational needs, but those that have, have demonstrated encouraging results. For example, Munoz et al. (2018) saw improvements in computational thinking for students on the autistic spectrum when using a Scratch based intervention. Similarly, in a separate study, the use of Scratch over an 8-week period saw learners with autism improve their social skills as demonstrated by observing their interactions with each other (Eiselt and Carter, 2018). However, there is a need to broaden these approaches and study the use of digital game making in fostering inclusion amongst the complex classrooms commonly encountered by teachers, which include students with special educational needs, potentially also in a mixed ability cohort.

This research therefore examines the utilisation of digital game making as a process for learning within everyday classroom teaching in non-STEM (science, technology, engineering, and mathematics) subjects with a focus on learners at risk of exclusion; specifically, those with assessed SENDs. The non-STEM subjects used in this study were identified as being relevant through discussion with teachers. This included utilisation of digital game making to teach history and key life skills, with teachers specifying that these topics would benefit most from novel methods of learning within the context of the study. The following section outlines past work in deploying digital game making in learning and highlights some studies that suggest benefits in fostering inclusive learning environments. The digital game making platform, Pocket Code, is introduced and the outline of two new studies that analyse its deployment presented. A feasibility trial analyses the method of using Pocket Code in the classroom and assesses the needs of learners for improved accessibility, whilst the full trial provides quantitative analysis of engagement and collaboration in the classroom when digital game making is used as a teaching tool compared with a control condition, supplemented with qualitative data derived from unstructured interviews with teachers. Conclusions and recommendations are made based on the findings.

2 Background

2.1 Game Creation & Digital Game Making

Game creation as a concept provides a flexible approach to learning; it can be applied to a complex system of modelling in the design of fully-fledged games or just the creation and utilisation of simple game assets. This is due, in part, to the "creation of knowledge" that forms through the process of creating a game (Kangas, 2009) and enables creativity while also making outcomes of learning tangible and personal to learners. We also know from research on game play how important collaborations are to motivate and sustain players' efforts to move ahead in the game (Kafai and Burke, 2015), and that teams can be productive learning groups (Ching & Kafai, 2008). Game creation provides a "shared goal" allowing learners to co-create the game and related artefacts strengthening group-based learning (Kangas, 2009). As such, digital game making could provide a lens through which to improve inclusion in learning within classroom settings by engaging learners and providing opportunities for collaboration toward a common goal.

Visual Programming Languages (VPLs), such as Scratch and Pocket Code, provide a platform for creating digital games and interactive media through simplification of programming concepts using representational building blocks and integration with pre-made templates. By removing the requirement to implement complex, text-based programming languages the cognitive barriers to accessible game creation are addressed. The goal of such platforms is to encourage the development of programming skills and to allow students to create content that is related to their interests (Resnick et al., 2009).

2.2 Digital Game Making & Skill Development

Scratch for digital game making has been utilised in several research studies within education to promote development of skills and cognition. In a series of sessions over 21-days, Baytak and Land (2011), utilised Scratch within a fifth-grade classroom focussing on the process of asset creation. Results suggest that the creation of artefacts promoted scientific knowledge while making programming knowledge “need-to-know” in the pursuit of goals. As stated earlier, this demonstrates the flexibility of the approach in providing multiple pathways to learning and provides ownership of learning outcomes.

A number of studies have focussed on the development of problem-solving skills through digital game making. Fesskis et al. (2013), for example, proposed that Scratch could improve problem-solving skills in children; their study suggested improved enjoyment in the learning process. Kalmpourtzis (2019), utilised a comparative experiment-based methodology and found that digital game making, when supported by appropriate teaching interventions, can have a positive impact on the development of problem-solving skills. Ke (2013) noted that digital game making increased positive dispositions towards mathematics in a study involving 64 participants over 6 weeks. Kalelioglu and Gulbahar (2014) also examined the effect of utilising Scratch programming as a means of improving problem solving skills. However, in their short-term study no statistically significant difference was found when comparing pre and post-test measures of problem-solving skills.

Tackling computational thinking is a common problem domain in research and while results suggest the games created only had moderate levels of complexity with regard to computational concepts there is a suggestion that such approaches may support the development of computational thinking (Wing, 2006; Kafai et al., 2014). Similar to computational thinking and problem solving, critical analysis skills may also be improved by learning through digital game making. Lye and Koh (2018) used a narrative approach to explore the challenges learners faced when using programming-based approaches and Akcaoglu and Green (2019) suggest an improvement in critical thinking when exposed to game design based learning.

2.3 Digital Game Making for Inclusion

In this section, the use of digital game making in encouraging inclusion in learning is discussed. Due to the scarcity of projects that focus on special education specifically, our focus is more broadly on any groups that can be defined as “at risk” from exclusion. The case is made that the concepts studied are transferable since those with special education needs form a subset of this group. Students' confidence with digital technology is linked to the actual activities in which they are engaged, with children at lower income and predominantly minority schools receiving less access to, and engagement with computing activities that focus on actual creation of digital content (see Margolis, Estrella, Goode, Holme, & Nao, 2008; Warschauer & Matuchniak, 2010 in Kafai and Burke, 2015). However, when access is provided, research suggests positive outcomes on engagement with learning.

Maloney et al. (2008), for example, found that the use of Scratch was effective in increasing engagement in programming for urban youth, citing the benefits of a simplified, multimedia-based approach. Here, engagement can be defined as a persistence in learning and a desire to continue to learn new concepts over time. Similarly, Gabriel (2018), suggests that student motivation and engagement increase when game design concepts are introduced into schools according to self-reported data gathered from teachers. It is notable that when discussing inclusion, studies often highlight engagement, and this seems to be a priority for teachers when assessing their students' behavior. Indeed, further work has suggested that such techniques can be used to engage the disengaged through self-directed modes of inquiry, where actors collaboratively construct new knowledge (Thumlert et al., 2018) by working together to research and co-construct new knowledge through production. Here the authors implement a “production pedagogy” which posits that people learn best through the development of artefacts that have value to them as makers. This mirrors points made previously dealing with asset creation and its ability to provide an engaging learning experience. However, there remains a need to expand on such work to examine and quantify the extent of such engagement when compared to traditional teaching methods and to examine the applicability of such approaches in the typical mixed ability classrooms commonly found in schools.

Such constructionist approaches to learning, as provided by digital game making, allow learners to better connect to each other and addresses issues of access by fostering a collaborative learning environment (Kafai & Burke, 2016). Here, in a review of over 55 studies, various methods of observing collaboration were evident in the works examined. Specifically, a broad definition of the term is used "whether it is working with others on the design or … sharing and exchanging designs" (Grimes and Fields, 2015).

Fisher and Jenson (2017) note that access to game and game culture is often restricted for girls but with game making they are active in the construction of their own subjectivities which in turn lifts barriers and provides ownership of learning. Furthermore, Denner et al. (2011) proposed that the creation of games in the classroom could improve the understanding of computational problems; particularly in female learners who may experience a lack of inclusion in such teaching sessions. Hence, the approaches described appear to provide learners with tangible outcomes to their study and an ownership of the process which promotes engagement. Indeed, engagement in particular, has been described as the single best indicator of learning, without which there is no deep learning (Iovannone et al., 2003; Hargreaves, 2006) and has been used to assess inclusion in special education in previous studies (Hughes-Roberts et al., 2019) where it is defined as time focussed on task.

However, there is little work that seeks to quantify the impact of such approaches when utilised in everyday teaching. This is particularly the case in mixed ability and special education classrooms that hold higher numbers of students at risk from exclusion. Indeed, while there are recent moves to make gameplay more accessible (e.g. Able Gamers Foundation and the Game Accessibility Guidelines) there is little research that intends to examine the use of digital game making tools and their accessibility for learning. As mentioned in the introduction, there are few studies that have focussed on digital game making and SENDs (Munoz et al., 2018; Eiselt and Carter, 2018); an area that requires further work.

Studies presented thus far suggest that digital game making can provide numerous improvements in cognition and engagement through collaborative approaches to learning. However, there is little data representing its effect on student engagement and collaboration in the classroom itself. Indeed, it has been pointed out that such affordances are often not used as a metric for evaluation (Kafai and Burke, 2015). In addition, while some studies have looked at the use of such technologies and practices when applied to learners at risk of exclusion, few have sought to explore impact when applied to special education and classrooms of mixed ability. Furthermore, studies assessing technology enhanced interventions in special education often lack robust evaluations, are small, or do not include a comparison or control group (Standen et al., 2014) and lack a clarity of methods that require a longer-term application (Denner et al., 2019), limitations which this research seeks to address.

2.4. Pocket Code

Pocket Code is an Android tablet-based, visual programming language environment built to allow the creation of simple to relatively complex games, stories and animations (Catrobat, 2017a). Pocket Code can be downloaded from the Google Play store and used on Android tablets and mobile phones.

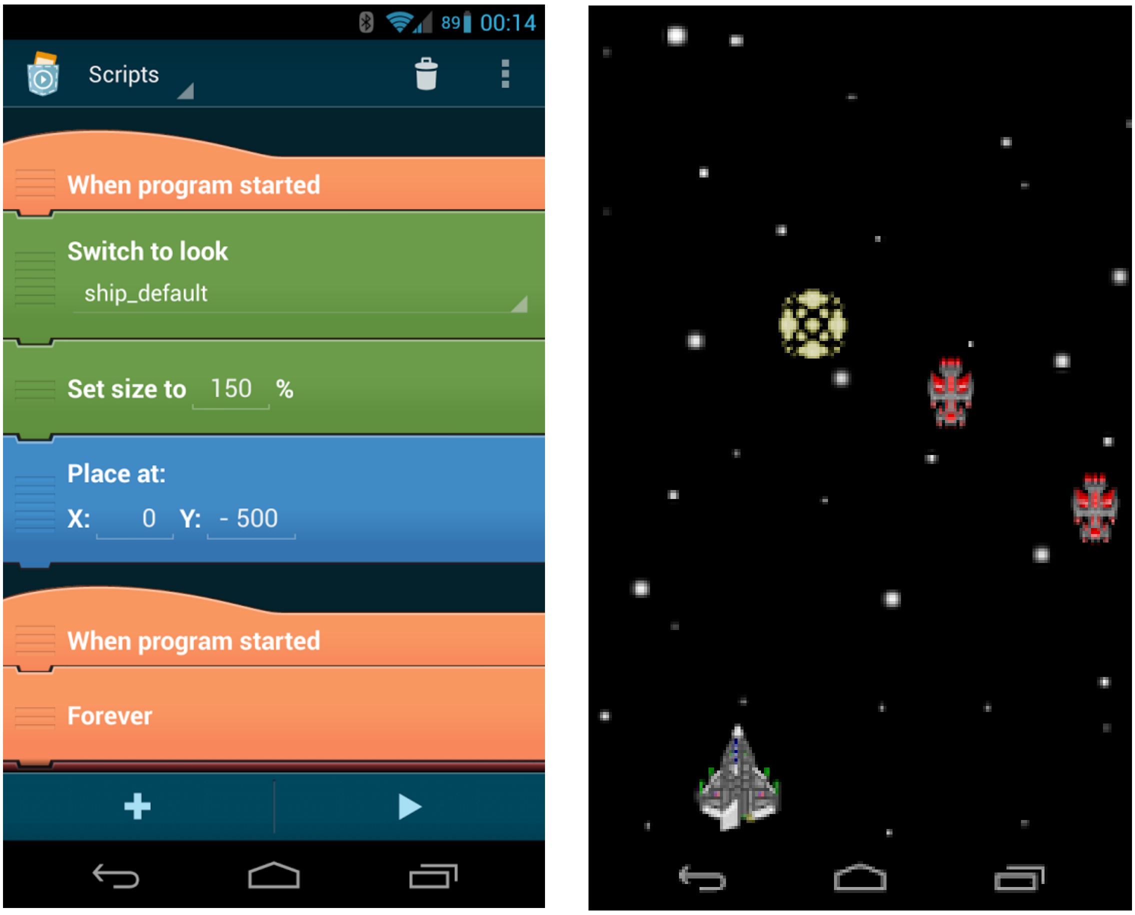

Figure 1 - Pocket Code (from Google Play Store)

The interface provides a variety of pre-defined bricks that can be joined together to develop animations and games. Each block is a programming statement represented as a visual description using common language, e.g. from figure 1, "When program start" sets the initial state of the game on execution, in this case loading the spaceship and its parameters including starting position. Complexity can vary from storytelling and animations using simple sequences of steps through to the use of far more complex programming concepts such as branching and loops (all represented by color coded, descriptive blocks) enabling creation of interactive games. Furthermore, users can download, edit and re-upload programs allowing the opportunity for peer-learning and collaboration through game sharing and remixing. Through the use of the camera functionality on tablets and a separate companion program, Pocket Paint, users can design and create their own assets for use in their programs. Pocket Code therefore offers an adaptive means of engaging with digital game making varying from constructing complex games to simply concentrating on asset creation, the focus of which can be the subject matter at hand in a teaching session. Learners therefore have multiple avenues for engaging with learning and can tailor their approach depending on their needs and abilities.

2.5. Research Aims

This paper examines the impact of digital game making using Pocket Code to teach UK national curriculum content to two cohorts of students in place of their usual teaching sessions. One of the two cohorts is taken from a primary school and can be described as a mixed ability classroom containing both neuro-typically developing students and those who have recorded individual educational needs; this represents a typical class of students found in a UK classroom. The second cohort is taken from a special education school and holds a group of students who all have recorded individual educational needs and are not learning at a national curriculum level due to their level of cognitive impairment. We define a game as an interactive experience that conforms to some rule base which includes narrative driven interactive stories with branching story choices. Broadly, the research questions are as follows:

- RQ1. What are the pedagogical implications for implementing digital game making in classroom teaching when delivering to mixed ability and special needs classrooms?
- RQ2. What is the impact of digital game making on classroom behavior with regard to engagement and collaboration?

This study differs from others in its use of defined metrics and methods for gathering quantitative data exhibited by learners when interacting with digital game making tools. Furthermore, this paper provides observations on usability and the lessons learned from such teaching sessions that are relevant to both practitioners and the research community at large for conducting further work in this area. Such observations are made through an action research-based approach that collected data from real world teaching sessions delivered under a national curriculum. The aforementioned feasibility trial was designed to explore RQ1 and guides the approach to implementing the intervention into a full trial to explore RQ2.

Engagement and collaboration are used as indicators for learning inclusion due to their pervasive use in past studies as discussed previously.

3. Feasibility Trial

The feasibility trial aimed to evaluate the deployment of Pocket Code as a new method of learning curriculum content with a view to making adaptations to both the platform of Pocket Code (e.g. improved accessibility), and the method of utilising it as a learning tool for the students in this study.

In order to evaluate the pedagogical implications for implementing digital game making into a coherent curriculum-based teaching strategy (RQ1), the feasibility trial aimed to determine the requirements and adaptations needed to be made to the original code base (Pocket Code) to make it suitable for use by SEND students, and thus produce the intervention required to enable the full trial to answer RQ2. We aimed to use this stage of the project to evaluate the means with which teachers would utilise digital game making and how this approach could be integrated into lesson plans. For example, it was not clear if pre-defined templates for games would be required and, if so, what game genres (e.g., Quiz, Adventure) would suit which subjects and which students.

3.1 Overview

The feasibility trial took place in two classes within two schools situated in the United Kingdom; the first, a mainstream school for primary education containing a mix of typically developing students aged 9-10 years. The second a special school supporting students with SEND, a subset of learners, aged 12-18, that exhibit a wide range of individual needs and where learning goals vary widely. Two teachers and one teaching assistant were involved in the trial; none had prior experience in programming. One day of training was completed prior to the study to familiarise all relevant parties with Pocket Code. This day was also used to define lesson plans and potential Pocket Code implementations in collaboration with the participating teachers to ensure our implementation's suitability in teaching to achieve national curriculum learning outcomes.

It is notable that the two schools chosen for this project differ in purpose and their students differ in ability considerably. Their inclusion in the project allows for the impact of digital game making to be assessed across multiple contexts and real-world teaching scenarios.

Each school was provided with tablets pre-loaded with Pocket Code. Tablets were numbered and individually assigned to learners to utilise throughout the trial; hence within each session each learner worked on their own tablet to tackle the tasks at hand.

A class of 30 in the primary school and a class of 12 students from the special school took part in the feasibility trial; within this first feasibility trial, no control condition was utilised. The purpose of this initial trial was to determine the pedagogical requirements for implementing digital game making into mixed ability and special needs classrooms. This included examining the teaching methodology and assessing the accessibility requirements of the original code base (Pocket Code) customising it to more formal learning environments.

3.1.1 Curriculum Development

The trial consisted of a weekly session spread over 6-weeks, each an hour in length and taking place within a typical classroom session. A standard session topic (e.g. history), learning objectives and content were converted into a digital game making session aimed at achieving the same outcomes. Content used in the primary education school dealt with Roman history (specifically the Roman games); while, in the special school, sessions focussed on key life skills.

For the history session, the learning objective was derived from the UK's national curriculum assessment objectives, specifically HA01 that deals with historical knowledge and fact/knowledge retention. A Pocket Code session was derived from content teaching the Roman Games; typically, students would keep a portfolio of work built up over a number of sessions which may include artwork, quiz activities, and complete teacher derived worksheets. Two implementations of Pocket Code teaching sessions were derived to deliver the same learning objectives. First, a bingo style interactive game that was teacher led and was used to convey concept identification by associating random definitions with their associated pictures; resources generated as part of this process can be found on the Catrobat website (Catrobat, 2017b). Here, students developed the game by creating assets and basic algorithmic design to add random item selection creating the rule set of the game. Teachers then led a session playing a version of the created game using the assets as discussion points to test knowledge of the topics. For example, when a particular historical object was selected by the game the class provided a definition/discussion as well as completing their bingo card on a companion application also created in Pocket Code. Secondly, students developed their own interactive story that dealt with an appropriate topic; for example, a competitor's experience during the Games. This would involve designing assets for use in scenes and generating basic logic to add animations, decisions and transitions within and between scenes. Teachers would aid in the creation of assets, help with programming concepts and ensure the created narratives were consistent with learning objectives. Pocket Code templates for interactive stories are also accessible through the Catrobat website (Catrobat, 2017c).

For the life-skills session, these students were typically operating below the national curriculum levels due to their individual needs and the focus was instead on general skills and aptitudes necessary for independent living. A typical teaching session may include reinforcing routines through repetition and practical demonstrations. The Pocket Code session included the development of interactive odd-one-out and quiz games with a focus on asset development (through practical application) (Catrobat, 2017d). For example, students may develop questions dealing with a morning routine and present their game to their peers for collaborative play. Hence, students would create a series of assets that may be related to a morning routine and the player would select the order in which they must be performed or select the odd one out from the range of options. Given the skill level of students, teaching assistants would provide prompts for what assets could be created and generate some of the basic logic for the games.

While a rigorous lesson plan was produced for each session, at this stage of the trial no pre-made content was produced for the coding elements of Pocket Code itself meaning participants started the lesson with a blank canvas in Pocket Code.

Sessions were delivered by a Pocket Code specialist in conjunction with the usual class teacher to refine the approach. Furthermore, within the special school, teaching assistants were present as would be the case in typical teaching sessions at this site.

3.1.2 Data Collection

The impact of the feasibility sessions was measured through the following means:

- qualitative observations during sessions to assess interaction with Pocket Code; an observer attended each session taking notes.
- teacher feedback following the sessions through un-structured interviews and semi-structured focus groups.

At the feasibility stage, an ethnographic approach was adopted enabling reflection on practice to identify changes to the teaching implementation in future trials. As such, teacher feedback was utilised to verify reflections from the practice reflection. Feedback concerning usability was analysed using a thematic approach using themes identified in similar work (Zubair et al., 2018).

The project was fully ethically approved, and parental consent obtained for each participant.

3.2 Observations and Teacher Feedback

The introduction of digital game making within the Primary school appeared to be mainly positive with teachers noting less instances of disruptive behavior occurring which would typically require their removal from the class; “they don’t want to risk not being in the class when using the tablets”.

Furthermore, individual students appeared to react differently to the teaching medium compared to how they usually would; “one student, who usually gets very upset when making mistakes, seemed much more willing to have a go and experiment with the code”. The more able students, having picked up the initial concepts earlier in the sessions, were observed helping less able students; the teacher suggested these students could become “digital leaders” as per similar schemes present in the school.

Within the school focussing on students with SEND teachers commented that the students appeared engaged, despite their low literacy levels which teachers identified as a potential barrier to their use of Pocket Code. Participants appeared “calmer” (teaching assistant) in comparison to typical classroom sessions. Furthermore, there appeared to be obvious pride in the work achieved with participants exchanging tablets with each other to demonstrate their games. Participants “particularly enjoyed using the camera and paint program to create assets to use in the game” (teacher). This highlights that participants with SEND, who may struggle with more complex coding tasks, can still engage with Pocket Code based sessions through asset creation thus providing some degree of ownership over the work produced.

From this informal observation and feedback opportunity, Pocket Code as an everyday teaching tool could provide a potentially engaging and collaborative learning experience. However, aspects of the delivery required some alteration. For example, starting with a blank template for game creation led to an increased amount of time working on the basics of program development rather than the intended subject matter. Teachers expressed concern that students were spending too much time learning programming rather than the curriculum material required. While student engagement with coding literacies are beneficial, the topics delivered here are non-STEM and have subject specific learning outcomes that may not be being addressed through programming-oriented activities. In response to this, lesson templates have since been integrated with pre-made game templates which can be downloaded and altered to fit a session. For example, a generic quiz game template can be adapted within the classroom with subject matter images, questions and answers. This would put learners into the role of multimedia designers which research suggests can also have a positive impact on motivation and cognitive development (Liu and Hsiao, 2002).

3.3 Accessibility & Usability Challenges

The variation in individual needs across the participants utilised in this feasibility trial provided a means of assessing the usability and accessibility of the Pocket Code intervention within a heterogeneous population.

The use of programming in game making holds significant challenges which must be overcome if it is to be a tool utilised in everyday teaching; particularly for learners with individual needs. As noted, teachers within this trial were concerned that their students spent time learning to code rather than learning the curriculum specific subject knowledge.

"The students did not have the ability to remember what we did last session; we had to revisit what the bricks do so we could carry on".

"Between sessions they couldn't remember how to use Pocket Code… some cannot recall the correct ordering or what individual blocks [bricks] do".

This would perhaps suggest that several participants within this sample struggled with the abstract ideas of programming inhibiting its use as a tool for subject learning. This suggests a need for careful adaptation of the User Interface (UI) to enable those with a cognitive disability to tackle the concepts found within programming (and to an extent digital game making). Conversely, these observations may be indicative of issues caused by time between sessions impacting knowledge retention; however, many SEND students also experience issues with memory and this was highlighted by teachers in the study. Similarly, possible institutional barriers may be evident with teachers prioritising the curriculum requirements placed upon them and the competencies provided by digital game making given a lower priority. Further studies should assess the impact of session timings on technical skill acquisition and seek to understand school/institutional barriers to digital game making adoption.

However, to produce an intervention suited to more formal educational environments and the needs of SEND students, teachers stated such students would perhaps benefit from software adaptations to the Pocket Code UI:

“There are too many categories [of bricks] within each script type; our students need less choice”.

Again, this would suggest that participants with a cognitive disability find it difficult to tackle the higher-level concepts that the bricks represent and the range of options available to these participants further hinders their ability to understand and apply the functionality offered. A solution could be found through personalisation of the Pocket Code environment through the provision of User Profiles where, based on the cognitive needs of the learner, only certain categories and their bricks are available. Indeed, Werner et al. (2014) suggest four levels of computational thinking related to the concepts of programming which can be used to evaluate understanding. However, such personalisation should be continually adaptable such that the full capabilities are available to students at appropriate moments in their learning pathway. Adaptations proposed are intended to be tailored towards students’ capabilities and not their limitations. Care should be taken in such implementations to avoid limiting what students can accomplish within the development environment, particularly in relation to their local classroom peers.

Identifying the computational concept each brick represents is a further challenge to these students due to the vocabulary and labelling used within the environment:

“The wording to describe the blocks is not appropriate for our learners”.

The use of words such as “forever” (to describe a loop) or “broadcast” (send parameters between objects) do not aid learners with cognitive disabilities in grasping the concept the brick represented preventing the application of that brick within a game. Teachers within the special school, where this observation was most prevalent, suggested that their students’ reading abilities were at levels which made it difficult for them to simply understand the words.

Teachers suggested replacing the text with symbols, such as Makaton, as utilised in their other learning material. This would enable the students with SEND to begin to grasp the concepts represented by the bricks. Similarly, the UI could be adapted to combine text, symbols and colors allowing eventual association between language and concepts. However, programming may require cognitive skills that some of these participants do not yet have preventing them from engaging with the session at all. As suggested in section 3.2, the use of game templates could provide a solution. Students could then interact with the session by creating assets related to the subject being taught and perform only minor changes to the coding blocks.

Various issues with physical disability were also identified which were often unique to subsets of participants; understandable, given the heterogeneous nature of classroom education. For example, some students found the text too small in formula editors, the use of color in labelling the bricks confusing and the interaction when placing a brick difficult where a drag and drop action would be easier. Whilst these usability issues are common, the range of issues observed across individual participants in this study highlighted the need for personalisation within the software to achieve a more inclusive learning experience. Future developments of digital game making applications could focus on adaptation of the UI on a user-by-user basis that addresses the requirements of both cognitive and physical disability. Issues identified here are consistent with those found in similar work (Zubair et al, 2018).

3.4 Considerations for Full Trial

Initial observations would suggest that digital game making tools can provide an engaging and potentially collaborative learning experience such that it could form a useful part of a teacher's toolkit. Hence, the following two hypotheses were proposed for the full trial:

- The use of digital game making in the classroom will increase learner engagement within a teaching session.

- The use of digital game making in the classroom will increase learner collaboration within a teaching session.

The feasibility trial concluded that changes to the implementation of digital game making as a teaching tool were required in order to cater for the unique cognitive, physical and sensory needs of the target students. Pre-made game templates were thus created that minimise the difficult task of coding during the session (Spieler et al., 2018) and instead allow participants to focus on curriculum learning through development of their own game assets. Efforts from the feasibility trial fed into a broader game making pedagogy that was part of the major project deliverables (Martinovs et al., 2017). This outlined a teaching framework using game templates that was then utilised as a teacher training and user guide for implementing digital game making for learning in the full trial and beyond.

4. Full Trial

4.1 Full Trial Overview

Following the feasibility trial, a full-scale module of teaching utilising digital game making principles was implemented within each school as summarised in Table 1:

Table 1 - Participant Overview

	Curriculum Topic	Class Size	Age	Number of Sessions	Comparative Control
Primary education School	History (Roman Games)	25	9-10 years	8	2 sessions with the same group
Special School	Life Skills (variety)	5	12-18 years	4	5 sessions with similar ability group

As per the feasibility trial, Pocket Code sessions utilised lesson plans developed from the usual curriculum-based plans provided by teachers which included additional sections to include computational thinking learning outcomes as well as subject discipline learning outcomes. However, based on the outcomes from the initial trial, pre-developed game templates were created to aid in the delivery of the sessions to ensure focus on the learning material rather than solely on programming itself. Two templates were designed for the full trial in relation to the session outlines provided in section 3.1; the first of these offered an outline of a quiz. Here, the template provided a single “look” or scene consisting of a question and a set of potential answers that took the form of graphics and/or audio. Default interactions were coded into the template for the quiz logic. Learners were required to add their own content to form the questions and answers and add additional looks for further questions thus expanding the quiz logic. Advanced features for more able students would include the addition of points, scores and timers.

The second template provided the framework for constructing interactive, choice driven narratives. Here, the template consisted of a look with placeholders for images and the logic for a branching choice, each option leading to a further look (i.e. if the user answers yes, go to screen one and no to the alternative screen). Learners were required to provide subject specific content to fill in the placeholders and drive the narrative. Advanced users were able to create more complex branching and additional looks.

Each of these templates can be found in the appendices to this paper and are available through the Catrobat website (Catrobat, 2017bcd).

Intervention sessions took place once per week replacing lessons that would have otherwise taught that topic in curriculum time.

To assess the impact of digital game making sessions, a bespoke observation tool, designed for the project, provided in-class behavior data. Each session was observed live by a trained researcher. Data gathered from typical teaching sessions serving as controls provided a basis for comparison. These control sessions were identified in discussion with teachers at participating schools based on what was possible for further observation without disrupting the school day; for the Primary School this was two further sessions with the same group of participants and teacher on a topic that was suggested (by the teacher) as being similar in delivery and learning outcomes: study of politics. For the special school, the control group consisted of six sessions with a separate group of students from the same class also studying life skills within sessions that would otherwise have been delivered. The activities in these controls mirrored the digital game making sessions, for example, students would storyboard their narratives or draw pictures for a paper-based quiz. It is noted that treating separate teaching sessions as controls potentially introduced some variability that cannot be accounted for and as such comparisons served as general indicator of impact.

While there has been much consideration of measuring engagement in education (e.g. Fredricks and McColsky, 2012) no psychometrically robust measures exist for children with intellectual disabilities (Hedgecock et al, 2014). We use time on task and time collaborating as effective measures of quantifying behavior to measure the study's impact in these sessions guided by previous research to determine how humanoid robots can support learning in children with profound and multiple disabilities.

This approach was deemed appropriate given the requirement to sample from a class of up to 30 students in order to gain a suitable measure of classroom activity over the session length. Other global measures are available to measure engagement, such as the scale developed by the Special Schools and Academies Trust (2011) as part of a classroom tool for teachers of children with complex disabilities. This use of this scale was not deemed appropriate for our study as it was not originally designed as an outcome measure but to encourage teachers to focus on the child's engagement as a learner and create personalised learning pathways, and requires rating of pupils in seven areas (awareness, curiosity, investigation, discovery, anticipation, initiation and persistence). Its use was not therefore appropriate for the simultaneous observation of up to 30 pupils.

4.2 Instruments

A behavioral observation tool, referred to above, was developed for the purposes of this study that focussed on capturing target behavior that occur over fixed intervals (Alessi, 1980). This in-class observation tool defines a variety of behavioral codes relating to teacher and student behavior, derived from the STROBE classroom observation tool (O'Malley et al., 2003; Kelly et al., 2005). The tool provides a means of sampling and classifying behavior throughout a session using a momentary time sampling approach; chosen as it is more likely to capture changes in behavior when compared to partial sampling (Rapp et al., 2008). Each session is split into 5-minute intervals within which several groups of observations take place. The first group deal with the structure of the class (e.g. whole class, or group work), the activity being conducted (instructional, procedural, inquisitorial etc.) and a general assessment of engagement for the class (half or less engaged, more than half, almost all etc.).

Following the group observation, the tool provided opportunity to record the teacher's behavior from a possible six codes (see table 2) and the student's behavior from a possible eight codes (see table 3).

Table 2 - Teacher Behavior Codes

Code	Teacher Behavior
1	Talking to entire class while all the students are passive receivers
2	Starting a discussion with the whole class or talking through a learning activity that students should be following step-by-step
3	Starting or conducting a discussion with groups
4	Monitoring groups of students (as they work independently)
5	Monitoring the entire class (as they work independently)
6	Asking class or individuals to show their work (during or at the end of sessions)

A record of the teacher behavior enables future analysis of whether the teaching style within the sessions differed to the control, and how the teacher behavior affected student behavior/interactions.

Table 3 - Student Behavior Codes

Code	Learner Behavior
1	Off-task – engaged with another behavior e.g. looking at phone or other material.
2	Off-task - disruptive to peer or peers.

3	Reading, writing, typing, listening – could be following the session but difficult to determine, could be waiting for the next instruction.
4	Following along with instructor or with learning material – e.g. off slides, from a book, in response to a request for help etc.
5	Receiving personal tutoring or interacting with teacher; demonstrating work to them etc.
6	Demonstrating work to another student. Receiving demonstration from a peer.
7	Working with another student or groups of peers to solve problems.
8	Wanting to participate/speak/demonstrate (arm raised) or actively participating - answering questions or demonstrating work to the class.

Within each 5-minute interval, measures were taken from four participants one after the other with each individual observation lasting 20 seconds. As mentioned, momentary sampling was utilised whereby the behavior observed at the end of the 20-second window was recorded on the observation sheet. A potential limitation of this approach is the under-representation of behavior, particularly were behavior length is shorter than the interval being used (Ary & Sun, 1983). However, a behavior of "engaged" as described in this paper should not have this issue as it is a more persistent behavioral state.

Using this tool, quantitative behavioral data is recorded during observation based on the activity being observed by a trained observer. Inter-rater reliability was considered as observers compared notes on a session observed as a group to ensure agreement on application of the broad behavioral codes. Furthermore, the study uses a mixed-method approach to validate and expand on the behavioral observations using teacher perceptions. As such, data gathering also included qualitative observations noted during the session as well as teacher feedback collected throughout the trial through unstructured interviews.

4.3 Data Analysis

To evaluate the research questions, observational data was recoded as follows; an observed code of one or two is “not engaged”, any other code is “engaged” with a further possible recode of six, seven or eight as “engaged” *and* performing “collaborative behavior”.

Data were then analysed using statistical software package SPSS 20. Descriptive statistics for engagement and collaboration were calculated from student observations as percentage of time those behaviors were observed. A Chi-Square test for association was then utilised to compare the observations between the two treatments using a significance level of $P<0.05$. Qualitative feedback was used to explore the data further and justify findings where appropriate.

5. Results

5.1 Data Summary

The observation tool deployed provided several intervals within a session (variable depending on session length) with each interval holding one teacher observation and four participant observations. Table 4 provides an overview of the number of intervals and observations gathered among the two schools for both intervention and control groups.

Table 4 - Observation Data Overview

	PE School	Special School
Intervention Sessions	8	4
Intervention Intervals	100	55
Intervention student observations	500	220
Control Sessions	2	5
Control Intervals	24	60
Control student observations	120	300

5.2 Engagement

Table 5 summarises the data following re-coding of the student observation to ascertain learner engagement.

Table 5 - Engagement Statistics

	Intervention		Control		Chi-Square Value
	Engaged	Not-engaged	Engaged	Not-engaged	
Primary School	86.7%	13.3%	81.5%	18.5%	P = 0.201
Special School	91.3%	8.7%	78.3%	21.7%	P < 0.001

Descriptive statistics suggest significantly more engagement within Pocket Code game making sessions compared to the control within the special school (Chi-Square P<0.001). This finding was not, however, confirmed with the primary school which despite holding a higher level of observed engagement, was not a statistically significant increase.

Figure 2 provides a breakdown of engagement within each session at the special school; also illustrated are the running averages (small dash) and final average (long dash) from the sessions conducted.

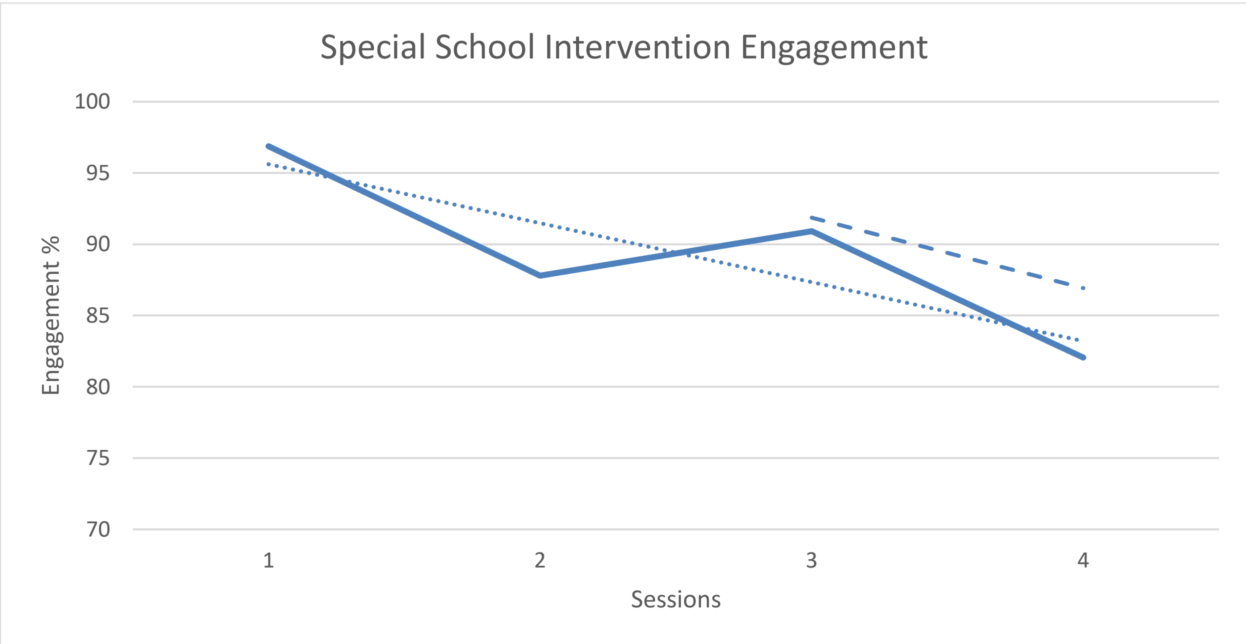

Figure 2 - Special School per Session Engagement

In comparison, figure 3 illustrates the breakdown for the primary school.

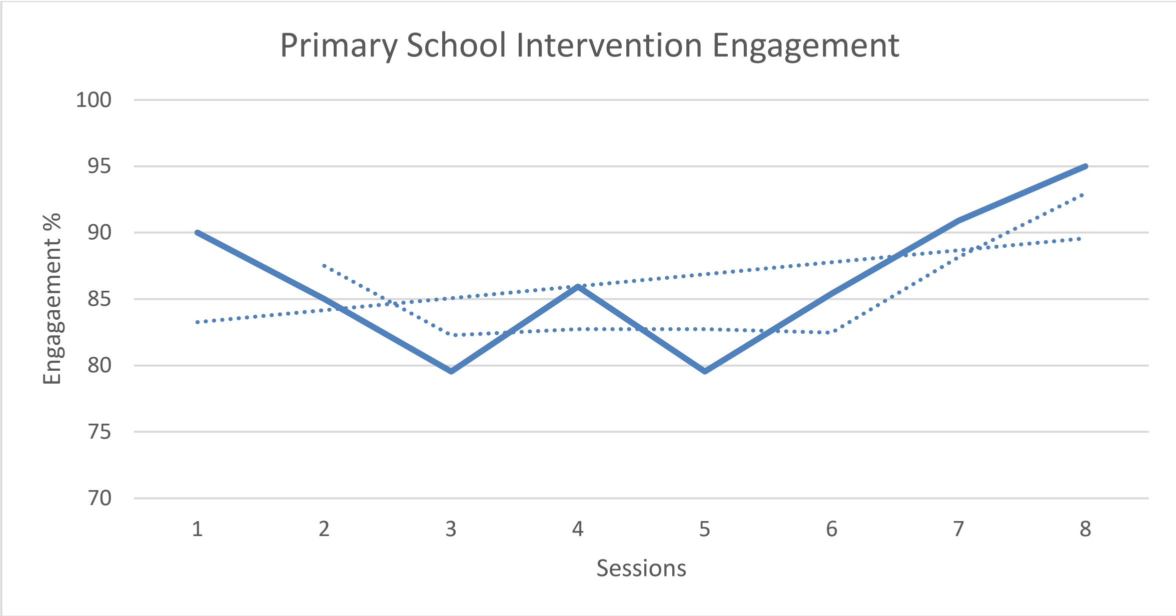

Figure 3 - Primary School per Session Engagement

5.3 Collaboration

The final three codes (see table 3) in the observation protocol determine potential collaborative behavior among peers; where student-to-teacher interaction is not counted as collaborative. The recoded collaborative behaviors are summarised in table 6 along with an analysis of difference with the control condition.

Table 6 - Collaboration Statistics

	Intervention		Control		Chi-Square Value
	Collab’	Not-Collab’	Collab’	Not-Collab’	
Primary School	12.8%	87.2%	6.5%	93.5%	P = 0.093
Special School	12.6%	87.4%	6.2%	93.8%	P = 0.021

Intervention sessions within the special school in this study found significantly increased observations of collaboration among participants compared to the control sessions (Chi-Square P=0.021). Although the primary school held a greater percentage in observed intervention collaboration, this was not statistically significant (P=0.093).

5.4 Discussion & Teacher Feedback

Table 5 highlights statistically significant results for the special school but not the primary school on both engagement and collaborative behaviors. The discrepancy between the two schools may be due to the simpler learning objectives within the sessions created for the special school. A higher-level focus on actual programming was deemed to be too advanced for these participants; and, from the feasibility trial, issues with cognitive disability were identified requiring tailoring of the digital game making material, via the use of templates, to the needs of these students. As such, intervention sessions within the special school tended to focus on asset creation for the games being made; for example, taking pictures for storyboards, recording sounds etc. Observations within these sessions suggested that this focus provided students with a clear sense of ownership over their work while the relatively simple use of digital game making principles allowed the students to focus on the tangible tasks at hand. Indeed, the participating teacher noted that while the students needed help creating the games, they were fully engaged in playing them when the session outcomes were achieved. Digital game making therefore encouraged participation in the construction of learning material and utilises the strength of gameplay to encourage engagement, as noted by Author (20XXd) where gameplay can provide a successful intervention for students with intellectual disabilities.. Engagement, for SEND learners, is often considered the single best predictor of learning (Iovannone, 2003), and so these results are encouraging for the adoption of digital game making as a teaching and learning tool.

While a statistically significant result was not found in the primary school, figure 3 suggests an upward trend in engagement following session 5 with a final session engagement observation of 95%. This upward trend would suggest also that any initial engagement observed due to a novelty factor may eventually translate into more persistent engagement that is the product of the strengths inherent in digital game making as a teaching tool. Indeed, the participating teacher noted a gradual adaption to the learning material: “The children are becoming more and more confident with taking risks … having a go at aspects of the lessons they are not 100% sure on” and “The children have started the sessions more settled … this may be due to the familiarity they now have with pocket code”. Interestingly, this may suggest an increase in learning persistence as learners appear willing to take risks and not be deterred by errors when they occur but instead see them as part of the learning process. Indeed, the participating teacher highlighted one particular student with individual needs: “This was particularly evident with [student] who is unable to focus for longer than a few minutes in most lessons. Throughout this whole lesson he was engaged in what he was doing, taking his time and making sure it was of a good standard which is something he can struggle to do at times in class”.

Interestingly, figure 2 exhibits a downward trajectory in engagement despite the statistically significant increase overall; however, there are fewer sessions and it is also worth noting that the final session 4 is around the point where engagement began to increase again in the mainstream primary school. An increase in the number of sessions is required to examine if the same pattern of engagement is consistent.

As in the primary school, teacher feedback was also positive suggesting that the narrower focus on asset creation enabled learning, but it was the tangible outcomes from the sessions that provided the most positive classroom experience, that is the final created games: “They are loving playing the games and increasing their scores”. Furthermore, the alterations to the delivery appeared to aid in overcoming the usability issues identified in the feasibility trials; “The students were working at looking at the colored blocks and trying to make the game look the same as the example [template]. I think they were using the shapes and colors of the blocks as he can’t read”.

Collaboration in the special school held a statistically significant increase as illustrated in table 6. Feedback from sessions suggest that students spent time demonstrating the assets they created to each other and how they work within their created games. This would further suggest that there were potentially increased amounts of learner satisfaction within digital game making sessions which should be explored further in future studies.

For the primary school, despite a seemingly similar percentage difference between the two conditions, it was not statistically significant suggesting that digital game making sessions are equally as collaborative as the typical teaching sessions used as controls. However, teacher feedback was positive and, again, suggest a persistence in learning that goes beyond the sessions: “The children are meeting their aims at the moment and the teamwork they have shown as a class is starting to now be used in other lessons. This is being modelled well during these sessions and recently we have started to see this behavior in both English and Maths lessons”. Due to the range of developing levels within this class, collaboration through teamwork has often been a problem; however, within the intervention session a potentially more inclusive environment was observed: “During the sessions this week I noticed teamwork between members of the class, which is something this class struggle with on a whole. Children who were progressing well used their initiative and went around the class to help members of the class which were struggling”. This feedback may suggest that the quality of collaborative behavior is improved in the intervention sessions.

6.1 Limitations & Further Work

Data has been provided to measure engagement and collaboration in mixed ability learners when engaging with digital game making in traditional curriculum-based teaching from two sample test sites. Each test site reported benefits, although only one site held statistically significant results. This could be due to the differences between the two samples and the content delivered to each of them. Further work should provide additional test sites to validate the results observed. While this research has focussed on implementing an intervention into a real setting and as part of everyday teaching, the approach is limited in providing a sample size that is generalisable to a wider population. This is compounded by the experimental setting offering a challenging research environment due to the complexity of embedding the work in a real teaching setting that has very heterogeneous populations. Past work by the research team has used matched pair control groups (Author, 20xxb); however, this approach has the challenge of finding suitable matches for complex students. As such, approaches subsequently were developed using within-group designs (Hughes-Roberts et al., 2019) that allowed the experiment design to have a formal control in challenging research environments. Future studies should broaden the sample size and, using the approaches developed here that build on past work, seek to validate the results further.

The methodology and the instruments deployed do not highlight learner satisfaction or the quality of engagement/collaboration beyond the qualitative observations provided by the involved teachers. The coding scheme utilised in the observation tool should be adapted in subsequent studies to include a wider variety of “learner states” for measuring more contextual impact. Although this work evaluates digital game making over a longer period of time and within a real setting, the implementation of the discussed teaching practices should be expanded to include more testing sites and increased exposure to digital game making to improve the generality of the results obtained. Furthermore, outputs from this phase of the project include game templates that require further evaluation to determine their long-term effect on learner engagement and to continue the co-design of digital game making as a rigorous pedagogy for utilisation within everyday classroom teaching.

Findings based on teacher feedback require further examination; this should be expanded on in future experimental iterations. For example, persistence in learning was apparent from a teacher’s perspective however, classes not involved in the trial would need to be evaluated to determine the extent of this persistence. Similarly, the methods employed in this study do not provide insight into the potential competencies digital game making encourages. These could include, for example, promoting creative thinking and artistic skill, improving literacy ability through scripting games and providing avenues to developing computational thinking through programming.

6.2 Summary and Conclusions

This paper has provided initial results from two trials examining digital game making using visual programming languages as a teaching tool in a mixed ability classroom and a school focussing on special education. Based on the research questions posed; the feasibility trial developed a pedagogical approach and identified metrics (engagement and collaboration) for measuring impact based on teacher recommendations. This approach suggested the need for pre-made content in the form of game templates that place the focus of sessions on the creation of digital asset content while still providing access to broader digital game making principles for relevant students. The need for learner profiles that ensured participants could access the platform depending on their capabilities was also identified.

A full trial then assessed Pocket Code using these metrics through a mixed methods approach to demonstrate the potential impact digital game making could have on classroom learning within two sample classrooms. This work has therefore provided both a methodology and initial quantitative data examining the levels of engagement and collaboration exhibited in two typical classroom sessions finding that such methods are at least as useful as comparable methods in the sample taken in this study. Findings also suggest means of implementing digital game making such that learners with individual needs are able to engage and benefit from the teaching sessions. These include the use of game templates that enable learners with cognitive impairments to focus on asset creation while still creating tangible outcomes from the teaching sessions giving clear ownership over the learning process. As noted in the limitations section, these do require further evaluation and development in subsequent works that should increase the sample across a wider variety of classrooms at varying school levels. This research therefore offers initial evidence for the potential of digital game making to enrich the learning experience within mixed ability classrooms and include and engage learners with special education needs by utilising the adaptability of digital game making.

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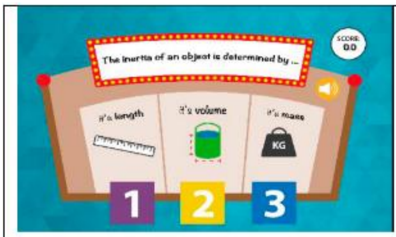
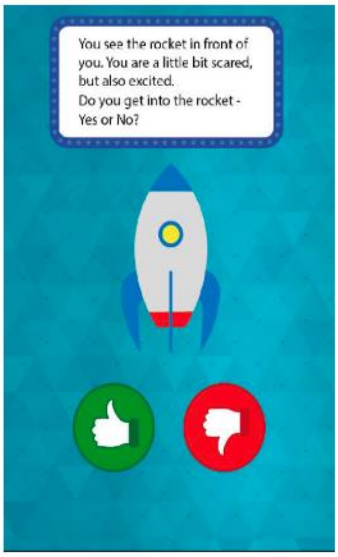
Appendices

Appendix 1 – Quiz Game Template



Create@School game created:		Quiz
	ID: 9992	
Description:	Question/answer with text and images (audio). Provide content per the questions.	
Gameplay:	Tap on one of the answers (1, 2 or 3). After answering the question, you get additional content. Switch to the next question by tapping.	
Enhancements by users:	Add looks and more questions.	
Learning goal:	Define questions to a certain subject/topic.	

Appendix 2 – Story Game Template



Create@School game created:	Adventure
ID: 9995	
Description:	Storytelling with linear choices.
Gameplay:	Listen to a question and decide "Yes" or "No". It is a linear game so one question will also lead you to the end of the game.
Enhancements by users:	Add content and sound files. Define more levels.
Learning goal:	For retelling a book. E.g. Help the characters to escape to a safe place (refugee stories) or answer subject related questions during the adventure.