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Making Mathematics Learning More Engaging for Students in Health Schools through the Use of Apps

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Abstract: This paper reports on an aspect of a case study of four 11-to-13-year-old students of a Regional Health School (RHS) in New Zealand, using apps on their own mobile devices as part of their mathematics programs. It considers the issue of engaging students in mathematical learning when they are recovering from significant health issues. The paper examines the influence of apps on these students' engagement with mathematical learning through the facilitation of differentiated learning programs. The research design was a case study with semi-structured interviews, questionnaires and observation used to generate the data. A number of themes arose from the data including both the positive and negative influences of apps on student engagement and the influence of apps on facilitating differentiated learning programs. The results indicated that using apps for mathematics had a positive influence on student engagement for most students. The positive student engagement seemed to be partly due to the apps' ability to support differentiated learning.

Keywords: engagement; apps; mathematics learning; health issues; students with special needs; mobile technologies; health schools; middle schools

1. Introduction

Students working in isolation when recovering from significant health issues have difficulty maintaining intentional learning experiences, let alone maintaining engagement with a coherent mathematics-learning program. There are also students whose attendance in schools is intermittent due to the mobile nature of their parents' employment or other social aspects. This is a critical issue for mathematics education in New Zealand, as although overall mathematics achievement has improved slightly according to the international assessment instrument TIMMS (Ministry of Education, 2012) [1] there is a significant tail in the results in mathematics achievement that indicates that some groups in society are not improving. As well, Māori and Pasifika students are over-represented in the statistics related to educational underachievement (Ministry of Education, 2013; TEC, 2009 [2–4]). At an individual level, this suggests an issue of equity and an issue of opportunity. While extrapolating findings from the study in the RHS to other minority groups where attendance is an issue is not possible, the findings can give insights into how using apps might enhance engagement with mathematics learning with these groups of students.

Three Regional Health Schools were established in New Zealand following Special Education 2000, a comprehensive review of special education in New Zealand (Ministry of Education, 1996) [5]. This review resulted in the role of teachers in hospitals being extended to include home-based students recovering from serious accidents or illness (Northern Health School, 2009) [6]. Many students are teenagers living with mental ill health or children and teens with cancer (Winder, 2014) [7]. To be eligible for the RHS service, students must be unable to attend their regular school for at least 10 consecutive days.

RHS learning programs are delivered in a flexible way depending on the circumstances of the student. Some students attend their school of enrolment (SOE) part-time, for particular subjects or times of the day. Some students attend Student Support Centers (SSC), which are classrooms at RHS centers, community buildings or in hospitals. These are open at a variety of times depending on the needs of the students and the workload of the teachers. They offer an opportunity to socialize and work on individualized programs alongside other RHS students (Hamilton, 2013) [8]. Some students are also enrolled in Te Aho o Te Kura Pounamu—the Correspondence School courses for particular subjects. Older students may participate in transition to work or tertiary education programs such as the Secondary Tertiary Alignment Resource (STAR). Some of the students work entirely in their own homes on a learning program the RHS teacher provides in consultation with the student's school.

RHS teachers work with the student's SOE to plan and deliver programs to attempt to ensure the positive benefits of education continue, despite students' health concerns. It is not unusual for students have as few as two one-hour visits per week from their RHS teacher. In between visits the students are expected to work on tasks independently. This can prove to be challenging for both students and teachers. Students' motivation and engagement are often adversely affected by illness. Teachers are challenged with providing support and engaging tasks, which facilitate meaningful learning experiences. However, the students also need tasks they can achieve without teacher or peer support, as they are frequently required to work independently. Another important part of the RHS teacher's job is supporting the student to transition back to their SOE when their health allows.

The RHS service caters for a broad spectrum of socio-economic groups with a considerable number of students coming from disadvantaged homes. Some IT equipment is provided in the Student Support Centers (SSC) and several teachers have participated in a scheme to purchase mobile devices that were subsidized by the school. A number of students, especially older secondary school students, own their own devices that they use to support their learning where appropriate.

Since the launch of the iPhone in 2007, the potential of mobile devices such as smartphones and tablets to personalize learning and enhance engagement has been noted by educationalists (Attard, 2013 [9]; Melhuish and Falloon, 2010 [10]; Traxler, 2010 [11]; White and Martin, 2014 [12]). Apps are small computer programs downloaded from the Internet onto handheld mobile devices. Some require connectivity to the Internet, while others can be operated independent of the Internet once they are downloaded. Apps are often free or available for the cost of a few dollars (USD) (Hutchison, Beschorner and Schmidt-Crawford, 2012) [13]. There are now many apps available to support learning. Traxler (2010) [11] noted that this type of anytime, anywhere learning was particularly beneficial for isolated students.

Meanwhile, other researchers contend that not all apps demonstrate what is considered effective pedagogical processes (Larkin, 2014) [14]. They are frequently digital versions of drill and practice games, albeit in a more dynamic, visual learning environment. Other apps offer opportunities to reshape the learning experience and for students to explore mathematical ideas in particular ways that enhance their learning (Sinclair, 2014) [15]. While there is huge potential for mobile technologies to positively influence both student engagement and cognition in mathematics, this depends on the learning situation and the pedagogical approach that the teacher employs (Calder and Campbell, 2016) [16]. This paper examines the influence of apps on student engagement through the facilitation of differentiated learning programs. In particular, we consider how including m-Learning in mathematics learning programs enhanced student engagement.

2. M-Learning

Smartphones, tablets, and iPods and laptops offer users the ability to access the Internet through Wi-Fi or mobile phone networks. These mobile devices can be used to browse the Internet or download apps. The term mobile learning or m-Learning has been coined to describe the phenomenon of "learning with mobile devices" (Traxler, 2010) [11] (p. 130). Another definition highlights the fluidity and broad scope of mobile learning defining it as "the processes of coming to know through conversations across multiple contexts among people and personal interactive technologies" (Sharples, Taylor, and Vavoula, 2007) [17] (p. 225).

Although not specifically designed for educational use, the proliferation of mobile devices and development of apps for educational purposes led to an excitement in the education community about their potential use as a tool for learning (Melhuish and Falloon, 2010) [10]. Several apps for education are exclusively available from the Apple app store but increasingly apps are becoming available for both Android and Apple. However, many pedagogically sound apps for Apple are unavailable on Android or Windows devices. The Window OS had few options for mathematics apps and a noticeable lower standard of graphics and pedagogical quality.

Some researchers contend that iPads were highly influential in student engagement, provided educators adopted a learner-centered pedagogy as part of a whole school vision for learning (Attard and Curry, 2012) [18]. They found that apps were fun, enjoyable and interactive for primary children and suggested that iPad usage in primary-school mathematics programs led to greater reflective practice, enhanced engagement and higher-order thinking (Attard and Curry, 2012) [18]. Meanwhile, Carr (2012) [19] indicated that the use of iPads and apps at times appeared to initiate higher order thinking and conceptual knowledge for students learning mathematics, by enhancing the students' engagement, practice and reinforcement of concepts. She also considered that teacher professional development and technical support were key elements of effective utilization of the mobile technology.

When examining the use of the iPad in literacy learning, Hutchison, Beschorner and Schmidt-Crawford (2012) [13] identified some generic advantages and considerations of using iPads that would be applicable to learning in mathematics. The feature of iPads to power on and off very quickly makes it easier to integrate them in a spontaneous manner, responding to arising opportunities without disrupting learning. In addition, students learnt how to navigate the iPad quickly, and worked collaboratively to resolve problems, leading to enhanced conversations. Given the specific nature of many apps, and the ease of including iPads in the learning experience, teachers were more likely to integrate the iPads into their lessons spontaneously, thus enabling some dynamic, responsive differentiation of the learning for individual students (Hutchison, Beschorner and Schmidt-Crawford, 2012) [13]. While educational apps are frequently game-based (Murray and Olcese, 2011) [20] and engaging, an important aspect of mathematics education apps is that the mathematics learning is embedded in the playing of the game (Masek, Murcia and Morrison, 2012 [21]; Moore-Russo et al., 2015 [22]).

Learning might also emerge and be reinforced through apps that evoke the use of multiple senses (Carr, 2012) [19]. With mobile devices such as smart phones, there is direct interaction with the phenomena, rather than being mediated through a mouse or keyboard, making the iPad more suitable for children than desktop computers (Sinclair and Heyd-Metzuyanim, 2014) [23]. Apps might use this haptic affordance with apps such as *Multiplier*, where within the task, the student drags out the visual area matrix associated with multiplication facts. This app also evokes multi-touch functionality, enabling students to make sense of individual effects of particular screen touches (Hegedus, 2013) [24]. The apps affordances of interactivity and instantaneous feedback foster the learner's willingness to take cognitive risks with their learning (Calder and Campbell, 2016) [16]. They allow students to model in a dynamic, reflective way. Others contend that MT can provide new forms of personal ownership (e.g., Meyer, 2015) [25] that in turn supports learners' personal understanding and conceptual frames (Melhuish and Falloon, 2010) [10].

Carr (2012) [19] recognized that game-based learning apps offered the potential to enable mathematical understanding and problem-solving processes. The features and quality of the app were not the only determinants of student learning with mobile resources though. Enhancement of learning was seen to be conditional on the apps selected, on the purpose intended and, in particular, on the pedagogical processes within which they were used (Calder and Campbell, 2016) [16]. It appears that a mesh of material and social elements influence the learning when mathematical phenomena are engaged through mobile technologies. This mesh of material and social elements include the opportunities and constraints that mobile technologies afford, their affordances.

3. Affordances

The term 'affordances' was created by Gibson (1979) [26] to describe the features of an environment in relation to the organisms that existed within it. "The affordances of the environment—what it offers, provides or furnishes, either for good or ill" (Gibson, 1979) [26] (p. 127).

Mobility, flexibility, ease of use and a range of applications were identified as some of the affordances for learning offered by mobile devices (Melhuish, Spencer, Coutts, Fagan, and King, 2013) [27]. Calder (2011) [28] specified a number of affordances for digital technologies in mathematics learning including the ability to create and explore multiple representations simultaneously; to create and interact with models in a dynamic way; to visualize situations; to get immediate feedback; to manage large amounts of data; and to enable the use of more realistic situations (Calder, 2011) [28]. He observed that integration of digital technologies into mathematics programs facilitated the modeling of mathematical situations which led to advanced mathematical thinking, promotion of visual reasoning and greater experimentation and risk taking. Meanwhile, Moyer-Packenham and Westenskow (2013) [29] identified several affordances specifically related to mobile technologies when students used apps in their mathematical learning. They were: focused constraint, where the app might focus students' attention on particular mathematical concepts or processes; creative variation, where the app might encourage creativity, hence evoking a range of student approaches and potential solutions; simultaneous linking, where the app might link representations simultaneously and connect them to student activity; efficient precision and motivation (Moyer-Packenham and Westenskow, 2013) [29]. Affordances do not typically manifest in isolation. They interact, and appear to be mutually influential on each other.

Mulligan and Mitchelmore (2009) [30] discovered that high achievers in mathematics had clear perceptions of visual representations of mathematical structure. This finding led to the implication that low achievers in mathematics will benefit from access to tasks that assist them in visual memory (Mulligan and Mitchelmore, 2009) [31]. The visual capability of apps means they can be designed to provide visual representations of mathematical structures. It is important for students of mathematics to engage with relevant, mathematics-rich activities that help them make links to their world (Anthony and Walshaw, 2007) [32]. Apps for mobile devices have the potential to provide such activities but there is a great variety in the quality of apps available, many with questionable mathematical pedagogical value. Larkin (2014) [15] investigated whether mathematics apps were appropriate in terms of the Australian content and the types of mathematics they promoted. He evaluated 142 mathematics apps against a range of measures that demonstrate effective pedagogy in mathematics and only recommended 34 of them for further evaluation and trial with primary school teachers and students.

The anytime, anywhere affordance of mobile devices may have negative effects. Kissane (2011) [33] expressed a concern that once the novelty value wears off and students engage with the large number of uninteresting apps, it may result in disengagement with the medium. Watkins (2013) [34] cautioned that some RHS students, particularly those with illness affecting mental health, could become negatively absorbed in their use of ICT. Nevertheless, the affordances of mobile technologies do offer opportunities to better enable differentiated learning programs for students in RHSs. This sort of differentiated approach to teaching and learning has a sound basis in educational theory.

4. Differentiated Learning

Differentiated learning was defined by Tomlinson (2008) [35] as an approach to teaching and learning in which the actions of a teacher are varied to meet the needs of students. Differentiation calls for teachers to have clear learning goals that are crafted to ensure student engagement and understanding. This requires the teacher to know their students' levels, interests and preferred modes of learning. Mills et al. (2014) [36] identified the need for teachers to take into account their students' cultural identities and plan programs and learning activities, which allow their students to make connections with others and with the content. Differentiated learning takes into account the fact that students are all individuals with different backgrounds, learning styles, passions, strengths and weaknesses. Tomlinson (2008) [35] asserted that differentiated instruction helps students not only master content, but also form their own learning identities, ideally, as focused, motivated, and independent learners. She claimed that learning is more strongly grounded when learning fits with students' prior knowledge, students have an awareness of their own learning strengths and weaknesses, and they have a voice in the learning process (Tomlinson, 2008) [35].

Differentiated learning connects with socio-cultural theories of learning developed by Vygotsky (1978) [37], who viewed learning as a social process where learners are participants in shared social activity supported by more competent peers or adults, followed by a gradual progression to independence. The zone of capability of the learner when assisted by a more knowledgeable other was termed the zone of proximal development (ZPD). Direction in this zone could take the form of guidance and collaboration, incorporating instruction and practice. The metaphor of scaffolding has been used to describe how a teacher might structure the task or environment in order to support new learning with activities such as modeling and providing feedback. Fading or withdrawing levels of support is also part of this process (van Oers, 2014) [38] as the learner moves towards independence. This approach has been shown to allow teachers to respond differently to diverse needs of students (McChesney, 2009) [39]. Communities of practice are part of socio-cultural theory. Learning is achieved, as the learner increasingly becomes a participant in the community. In the case of a mathematics classroom, the community is learning how to learn, understand and use mathematics.

In recent years, it can be argued that the concept of differentiation has been extended to a model known as personalized or individualized learning (Burton, 2007) [40]. Personalized learning extends differentiation to encompass the 21st century learning value of innovation—of applying knowledge in inventive ways and presents an alternative to 20th century mass school systems. Leadbeater (2011) [41] described a learning environment where learners are encouraged to find their way into flows of knowledge that are constantly changing, through collaboration and use of technology. Learning is created through interpretation, both individual and social. The learner's existing knowledge influences development of new understanding. Learners actively select or reject information from experiences and, in making sense of these, continually reorganize their knowledge (McChesney, 2009) [39]. There is an acknowledgement that the teacher does not know all the knowledge required and there is potential for students to create their own new knowledge through collaboration and their own inquiry.

Although there are subtle differences, most notably the focus on the students' voice and active role in directing and evaluating learning, the principles of differentiated and personalized learning are similar. For the purposes of this article, the term "differentiated learning" will be used to describe the concept of adapting a learning program to meet an individual's learning needs. The next section will discuss how e-learning might facilitate differentiated learning in the RHS context.

There is potential for e-learning to be an effective tool for helping RHS students in their pursuit of individualized learning goals and in maintaining their connections with others while they are in a potentially isolating situation (White and Martin, 2014) [12].

5. Engagement and Motivation in Learning

With their potential to facilitate differentiated learning, apps for mobile devices also have the capacity to influence engagement of learners. The concept of engagement has been defined in a range of different ways. In this paper, engagement is viewed as a multi-faceted construct, which operates at three levels: cognitive, affective and behavioral (Fredricks, Blumenfeld, and Paris, 2004) [42]. Cognitive engagement requires a student to recognize the value of learning and demonstrate a willingness to invest in it.

Affective engagement includes the student's thoughts and beliefs about school, teachers and peers and how those influences affect willingness to be involved with schoolwork. The affective domain describes the way a student thinks, feels and believes. In mathematics, and any other learning area, the affective domain has been shown to influence a student's ability to learn and to apply their learning to the real-world context (Frid, 2001 [43]; Grootenboer, Lomas, and Ingram, 2008) [44]. A student's actual knowledge can be hidden by a debilitating student attitude (Grootenboer, 2001) [45].

Fredricks, Blumenfeld and Paris (2004) [42] asserted that active participation is the hallmark of behavioral engagement. It is considered crucial to the achievement of positive academic outcomes. Likewise, motivation is not observed directly, but marked through behavior and attitudes. Hannula (2006) [46] described motivation as a preference towards doing some things and avoiding others. Motivation is related to personal interest (Waege, 2010) [47] and plays a role in student achievement. Others have reported positive correlations between students' positive attitudes and sense of autonomy, and enhanced learning and performance in school (e.g., Deci and Ryan, 2000) [48]. There appears to be a relationship between motivation and engagement, with peer pressure and classroom culture influencing students' learning opportunities in mathematics (e.g., Sullivan, Tobias, and McDonough, 2006) [15]. Positive student perceptions of the quality of instruction increase their enjoyment of the learning and alleviate feelings of anxiety towards mathematics (Frenzel, Pekrun, and Goetz, 2007) [49].

In mathematics learning, engagement occurs when students enjoy learning and doing mathematics, and they view the learning and doing of mathematics as a valuable, worthwhile task, useful within and beyond the classroom (Attard, 2011) [50]. A teacher's pedagogical practices, including the integration of technology was found to have a significant influence on student engagement (Attard and Curry, 2012) [18].

Self-efficacy, the belief in one's own ability to learn, is crucial to engagement (Bandura, 1997) [51]. For students with low self-efficacy in mathematics, Gee (2005) [52] observed computer games providing gamers with opportunities to take risks and learn from their mistakes in a non-threatening, fun environment. Pierce and Ball (2009) [53] demonstrated that using ICT and especially apps for mobile devices was highly engaging for students of all levels.

Malone and Lepper (1987) [30] were interested in designing intrinsically motivating learning environments. According to their taxonomy of intrinsic motivation, motivation was enhanced through challenge, curiosity, control, recognition, completion and co-operation (Malone and Lepper, 1987) [30]. Learning that was fun appeared to be more effective (Ciampa, 2014) [54]. Well-designed apps for mobile devices have the potential to meet all these attributes for motivating learning experiences.

A lack of motivation and engagement are significant barriers to learning in the RHS context. Long-term illness in individuals can cause low confidence and low self-esteem (McNeish, 1999) [55]. Despite some concerns about some students' negative absorption in ICT, the teachers who participated in Watkin's (2013) [34] research in the RHS context perceived that e-learning programs, especially those with an interactive element, were more engaging or motivating than book or paper-based programs (Watkins, 2013) [34].

The importance of feedback in student achievement has been firmly established (Black and Wiliam, 1998) [56]. In situations such as the RHS context, where immediate feedback from the teacher or peers is not always possible, apps may provide a positive alternative to traditional paper tasks. Giving immediate feedback is an affordance of mobile technologies (Calder, 2011) [28].

In the RHS context, there is a need to provide differentiated learning programs for a diverse group of students. Motivation and engagement can be problematic in this group due to their health issues and lack of contact time with teachers and peers. The increasing access to Internet connected mobile devices such as smartphones and tablets presents an opportunity to offer relevant interactive tasks to support students' learning goals. Integrating these devices comes at a cost in investment in hardware and systems, along with investment in teacher professional learning. There is evidence in mainstream education that using mobile devices to support learning is engaging. Is this also true in the RHS context? Is it worth investing resources in? What are the limitations of using apps? These questions led to the design of this research project to try to shed some light on the question: In what ways do apps for mobile devices influence student engagement through facilitating differentiated learning programs?

6. Methodology

The research was situated within the interpretive paradigm, based on a belief that human reality is multi-layered and complex (Cohen, Manion, and Morrison, 2011) [57]. A phenomenological approach was used with the thoughts and actions of the individuals examined through a range of lenses (O'Hara, Carter, Dewis, Kay, and Wainwright, 2011) [58]. The conclusions and implications were guided by the open-ended research question and emerged from the data collected. In keeping with the interpretive or naturalistic paradigm, a range of methods was used to collect the data (Lincoln and Guba, 1985) [59].

A case study methodology was chosen due to its capacity to reveal in-depth data on an individual's thinking. Case study results are generally easily understood and they may illuminate issues or findings, which are lost in larger scale data such as surveys. They are flexible enough to be undertaken by a single researcher and accommodate unexpected events and variables (Yin, 2016) [60].

Teachers at two regional centers of a New Zealand RHS were invited to take part in the research and nominate interested students to participate. The students were in Year 7–10 (aged between 11 and 15 years) and had relatively easy access to a mobile device that could have apps loaded onto it. Year 7–10 students were more likely to be on the RHS roll for at least three weeks, which was required to complete the data collection. Experience as a teacher in the RHS showed that many students in the Year 7–10 level had gaps in basic number knowledge. Many mathematics apps address basic number knowledge so incorporating them into their program was likely to benefit their learning. Students older than Year 10 would be less likely to benefit from basic number knowledge apps and would be focused on NCEA so involvement in the study may have detracted from their learning. Four students from one regional center of the RHS met the criteria and volunteered to participate. One RHS teacher who worked with all four students participated in the study.

Procedures

The four student participants were visited individually at their homes or their SOE, as is normal practice for RHS students. They completed a questionnaire and participated in a semi-structured interview to ascertain their attitudes to mathematics. Their attitudes towards using technology in learning mathematics and their experience with using technology in their mathematics learning were also canvassed. The semi-structured interviews were recorded and lasted approximately 20 min.

Data provided by the RHS teacher on the students' mathematical levels and interests were used to select apps for each student.

Table 1 shows background information about the participants collected from the questionnaire and in the case of the Numeracy Development Project (NDP) stages, from the RHS teacher. These stages range from 1 to 8, with 8 the highest.

Table 1. Student Participants.

Students	Gender	Age	Year Level	NDP Stage
Sarah	F	11	7	5
Jake	M	11	7	5
Amanda	F	11	7	4
Keiko	F	13	8	4

Apps that appeared to target areas of need for the students were selected for each student. They were predominantly skill-based practice apps and only free apps were used. At the first visit, after administering the questionnaire and conducting the first semi-structured interview, selected apps were downloaded onto the students' own devices. Following that, the participants were taught how to use the apps where necessary and observed engaging with the apps for approximately 15 min.

Table 2 displays the apps that were loaded onto the student devices. They largely addressed basic number knowledge objectives such as quick recall of addition, subtraction, multiplication, division facts and fraction recognition. *Math Slide 1000* focused on place value. *Tangram Sam* had a geometric component. S*quare Puzzle* and *Where's my Water?* required application of logical thinking and problem solving skills.

Table 2. List of Apps Loaded onto Student Devices.

Students	Names of Apps
Sarah	MathTappers: MultiplesSuper 7 Pizza Fractions 1 Bubble Pop Multiplication Bubble Maths
Jake	Kosmic Math HD Math Slide 1000 Pizza Fractions 1 Super 7 Bubble Pop Multiplication
Amanda	Math Magic Square Puzzle Tangram Sam Where's my water? Math Tutor
Keiko	10 monkeys Multiplication Math Slicer Where's my water 2? Math Magic Simply Fractions Lite

The students used the apps independently for three weeks. They were emailed questions to prompt feedback on how the apps were going after 7–10 days. After three weeks, the participants were re-interviewed and asked how the apps had influenced their engagement and learning. The teacher took part in a semi-structured interview after three weeks and reported on her impressions of the students' engagement and her experiences of using apps for mathematics in her teaching practice.

The research question that underpinned the study was: In what ways do apps for mobile devices influence student engagement through facilitating differentiated learning programs? Ethical approval was gained from the University of Waikato, Faculty of Education Ethics Committee (EDU025/14) [61].

7. Results

The data collected from the student questionnaires, email, semi-structured interviews with students and teacher and observations were analyzed for themes in relation to the research question.

7.1. Student Engagement

Cognitive, affective and behavioral factors were considered when analyzing the data for how the apps affected participants' engagement in learning mathematics. Assuming engagement occurs when students enjoy learning and doing mathematics, and they view the learning and doing of mathematics as a valuable, worthwhile task, useful within and beyond the classroom (Attard, 2011) [50], data were analyzed and organized into themes of positive and negative engagement. Within the positive engagement theme, there were comments about fun, usefulness of apps, and students' expressions of a willingness to invest and actively participate.

7.2. Positive Student Engagement

Three of the four participants demonstrated positive student engagement in using apps in their mathematics programs. In the second interview, they reported that they used the apps every day and were doing more mathematics independently than previously. When they revised their questionnaires after using the apps for three weeks, their ratings stayed the same or rose, often to the top of the scale. The highlighted cells on the table of quantitative questionnaire results (Table 1) show the questions where students' ratings increased. In the Likert scale, 1 was a negative response to a question, "very difficult", "not much at all" or "not good". A rating of 5 was a positive response such as "very easy", "I like it a lot" or "very good".

These three participants ticked at the top of the scale "very good" when asked how they felt about using apps as part of their mathematics program. They said they would recommend using apps in mathematics programs to other students of the RHS and would like to keep using them themselves.

> "It [apps for mathematics in the RHS] works very well. Me and Jake have been enjoying playing together lots on it [on Math Slide 1000]." (Sarah, Interview 2)

The fourth participant, Keiko, had a much more negative attitude to mathematics in general and low self-efficacy compared to the other participants (see Table 3). She did not find using the apps engaging for herself but interestingly she did say that she would recommend them to other RHS students. She did appear to prefer using technology than traditional methods to learn mathematics however, as can be seen from this observation.

> The teacher began working with the student. At first, she could not get the Internet connecting on her iPad and started to get out written worksheets. The student took over the iPad and managed to connect to the Internet and start working on the MathsBuddy website. She had done some lessons independently on it during the week. They discussed that MathsBuddy had clips explaining concepts as well as exercises to complete, both of which the student had found helpful. (Observation)

Table 3. Table of Student Attitude Rating Responses to Questionnaire before and after Using Apps.

Questions	Student Participants							
	Sarah		Jake		Amanda		Keiko	
	Before	After	Before	After	Before	After	Before	After
Do you have maths apps on your mobile device already?	Yes		Yes		No		No	
How easy do you find it to stay on task when you are doing maths?	5	5	3	4	3	3	1	1
How much do you like doing maths?	5	5	3	4	3	5	1	1
How good do you think you are at maths?	5	5	3	4	Don't know	Don't know	1	1
How good does your teacher think you are at maths?	Don't know	Don't know	4	5	Don't know	Don't know	Don't know	Don't know
How good do your parents think you are at maths?	Don't know	Don't know	5	5	5	5	1	1
How much do you like doing maths on your own?	5	5	3	4	3	5	1	1
How do you feel about doing things in maths you have not tried before?	2	2	2	3	5	5	1	1
How much do you like doing maths in your own time?	5	5	3	4	3	5	1	1
How do you feel about learning or doing maths as you get older?	5	5	4	5	5	5	1	1
How do you feel about using apps as part of your maths programme?	5	5	4	5	5	5	Don't know	1

Notes: Before: Questionnaire responses at first interview before using recommended apps; After: Questionnaire responses at second interview after using recommended apps; 1–5: Attitude rating on Likert Scale: 1 indicates a very negative response, 5 a very positive response; Colored highlights: a positive change in responses between visits.

Enjoyment can be considered as a predictor of student engagement. There was evidence to support the notion that apps were fun and enjoyable for the students.

> "They're fun cos I'm playing Slide 1000... I'm starting to really like doing maths a lot more."

The teacher also had observed the students enjoying using apps.

> "It's another wonderful tool isn't it? So many of them love it. They've all grown up with TV, PSP [PlayStation Portable], all those things so now the app world is very exciting to them . . . so much more exciting than us with our rote world." (Teacher Interview)

Two of the students were markedly more engaged and focused when experimenting with the apps than during the interview prior to loading the apps on their devices. One was quiet, hesitant and appeared to lack confidence during his interview. When he began experimenting with the app *Math Slide 1000*, an app that focuses on representing place value in a variety of ways, his demeanor changed and became animated and enthusiastic. This exchange occurred after he had played one game of it.

> Teacher: We better call it quits there.
> Student: One more game! One more game!
> Teacher: Shall we let Helen (the researcher) play too?
> Student: Let's do three players.
> The researcher joined the game.
> Student: Are we ready? Go 3 2 1 Go! (Observation)

The three participants, who were positively engaged with the apps, believed that the apps were useful and were helping them with their learning. Sarah's reply to the email question asking if she was doing more or less mathematics by herself than before was that she was doing "more and it is helping me lots" (Sarah, email response).

Amanda also found an app helpful despite using a Windows phone, which had very limited options of quality apps.

> *"The Magic Tutoring [app] was helpful."* (Amanda, Interview 2)

These three students believed that they were able to learn mathematics and indicated that the apps were helping with their self-belief and self-confidence. As per Bandura's (1997) [51] findings, self-efficacy is a crucial part of self-motivation and success in learning.

Amanda and Sarah had previously indicated a more negative attitude to mathematics. Amanda mentioned in her first interview that the RHS teaching was helping her feel more confident in her ability to learn mathematics. She said that multiplication was her least favorite part of mathematics but, "Now that I'm learning it's getting good". Introducing apps into her mathematics program appeared to support her increasing confidence in her ability to learn.

> "I hated math but now I am kind of getting to like it, just cos I know how to do it." (Amanda, Interview 2)
> It's been more positive and I've been more happy and it's been helping a lot. All the results I've been getting has been making me feel happier. (Sarah, Interview 2)

Mrs Kendall had also observed engagement and feelings of positive self-efficacy in these three students.

> I just loved seeing their enthusiasm for it, their confidence. I just loved them ticking up the top of the scales on their surveys. These are kids that most of them see themselves as failures in maths so to see that was lovely.
> Interviewer: Even though their level might not have changed that much?
> Teacher: Absolutely, they believe it and once they start believing I'm sure they'll start improving. (Teacher Interview)

The three students who displayed positive engagement were willing to invest their time and effort into using the apps. They all reported high ratings for liking doing mathematics in their own time following having the apps for three weeks. This indicated a level of active participation in their learning and a belief in its relevance to the world outside the classroom, which is another indicator of engagement. Like Jake, Sarah was more focused during the trial of apps than in the interview. She was keen to use the mathematics apps when given free time when they could choose what to do.

> "I get it all done in the nick of time and I have time to play free games but I choose to play maths games instead. (Sarah, Interview 2)

Peer, teacher and family influences can have an impact on student engagement. There appeared to be a link between positive family attitudes towards using the apps and positive student engagement as seen in the answers to the question, what did your family think about you using apps for mathematics?

> "They like it. They check if I've done it every day." (Jake, Interview 2)
> "They thought it was really good, especially my sister, the little one . . . My Mum plays it too. We try and challenge each other." (Amanda, Interview 2)

When asked to name three important things a person needs to learn to be good at mathematics, two of the students—including Keiko, the one who was most negative about mathematics—acknowledged a positive attitude was important in learning to be good at mathematics.

> "They need to be positive about it" (Amanda, Interview 1)
> Keiko: Attitude
> Interviewer: Do you mean a positive attitude?
> Keiko: Yes (Keiko, Interview 1)
> Negative Student Engagement

Although most students were positively engaged with the apps, they all had some experiences that impacted negatively on their engagement.

Keiko displayed a negative attitude towards almost any type of mathematics, including apps.

> Keiko: I didn't like them.
> Interviewer: What didn't you like about them?
> Keiko: I don't know. It's math (Keiko, Interview 2)

Keiko also expressed an opinion that the apps were boring. Other participants echoed this opinion.

> "It's just a bit boring . . . it just gets really boring." (Observation of Jake, when trying *Bubble Pop*, which had confusing visuals)

Some apps were not pitched at the right level for the participants and they found this frustrating and disengaging.

> "[Some of them were] too easy and some were too difficult to do." (Amanda, Interview 2)
> "Because they were a bit harder. They weren't as creative and fun." (Sarah, Interview 2)
> "I know some of them start quite low and they lose interest because they're not willing to wait." (Teacher Interview)

The cost of apps had an impact on engagement. Many quality apps, that might have been recommended, cost to download. None of the students had any money on their mobile device accounts so that they could load more paid apps independently. Some apps were used that could be upgraded for a fee. This led to frustration for Jake with *Kosmic Math HD*.

> Jake: There's only one problem with it . . . you only get to do three levels. Every time you quit off it for a while it restarts and you have to do it again and if you get lots of them you can collect an alien puzzle piece but I can only get three but if I had the whole solar system I could collect the whole puzzle.

> Interviewer: Do you have to buy the app to get all the puzzle pieces?
> Jake: Buy it yeah. (Jake, Interview 2)

Mrs Kendall also experienced difficulty recommending paid apps to families.

> "Some of them cost. I'm encouraging them to do it at home but I don't know if they are." (Mrs Kendall, Teacher Interview)

Despite some limitations and personal differences, on the whole apps for mobile devices were a positive influence on student engagement. The affordances of using apps to facilitate differentiated learning are considered next.

8. Differentiated Learning

Some of the affordances of apps for learning mathematics relate directly to supporting differentiated learning. These results indicate that apps have the potential to facilitate differentiated learning programs through providing learning tasks that support the different learning goals and levels of students; encouraging self-management and student autonomy and appealing to different learning styles, interests and personality types.

Effective teaching requires diagnosis of learning needs, planning a program to meet those needs and summative assessment to check that the desired outcome has occurred. In the RHS context, especially when teachers do not have much contact time with the students, both the student and teacher participants considered that apps have the potential to support learning goals in mathematics, especially in number knowledge, through providing engaging activities pitched at appropriate levels for the students.

> "I think they're great. (for differentiated learning) . . . I think most apps are pretty clever because some of them are being designed now . . . for example if they are getting 9x tables wrong they'll throw those sort of questions in more. I think that's really clever. If the app designers could keep doing that. I like it better when you can program in a level rather than whatever that one was that started really low and they had to keep progressing." (Teacher Interview)

> "Because this Pop Maths you get to choose the level and get to use different types of maths (Sarah, Interview 2)

Learning is more engaging and effective when students feel they have some control over what and how they are learning. Apps have the potential to allow students opportunities to identify and work towards their own goals.

> "I usually practice my 9s, 11s and 12s because they're the harder ones for me." (Sarah, Interview 2)

Possessing the willingness to take risks and persevere towards their goals is another attribute of successful learners. Some students were more prepared to take risks than might have been expected, with their health concerns and low mathematical achievement. Jake was observed experimenting with Kosmic Math HD. He chose a level adding two digit numbers. To begin with, he got five or six answers incorrect in a row. The time limit was short and the level appeared too difficult. The teacher and researcher were concerned he might lose confidence and asked if he wanted to try another level but he ignored us and persevered until he employed his strategies and got four answers correct in a row and excitedly said:

> "That's 50%, that's 100%... oh well at least I'm going to land it and collect an alien.. so watch this I'm going to collect an alien . . . see watch this, look at this! [Reading] Great job! Planet trip successful. You have found an alien puzzle piece. (Observation of Jake)

There were concerns that some students may feel under pressure or stressed by the speed of the questions or getting answers incorrect, especially with their health issues. However, none of the students reported feeling anxious. Somewhat surprisingly, the only positive comment that Keiko had to say about using apps was that they she liked that they were "kind of competitive".

The apps helped with differentiating the learning programs for individual interests and ways the students preferred to learn. Jake was interested in space and vehicles so some of the apps chosen for him appealed to those interests and did appear to help with positive engagement.

> "I'm finding I like that Space Maths (Kosmic Math HD)". (Jake, Interview 2)

Sarah expressed a preference for doing drill type exercises rather than games.

> "(I've got) some fun apps and I'm into the serious ones though. I just found that out ... They're not kiddy ones that are like how do I say it? They're not more gameyish ... More like worksheets but Internet ones." (Sarah, Interview 2)

Engagement Affected by Technical Issues

Internet access was an issue at times. Two of the student participants were visited at home and were able to access their family's Wi-Fi network to easily download the apps. The other two students were visited at their school of enrolment. The school had provided Wi-Fi access but it was only working very slowly. Moving around the school did not make any difference. The apps appeared to download but the pictures were not visible. They finished downloading when a mobile phone was used as a hotspot. Sarah was distracted by the difficulties connecting to the Wi-Fi.

There were other technical issues that interrupted the flow and negatively affected engagement. When an attempt was made to load the new apps onto Jake's device, he did not know the iTunes password. Fortunately, the RHS teacher was able to contact his parents by phone and they told Jake who typed it in. Keiko's phone battery was almost flat when downloading her apps. Her charger was not working properly and her phone turned off periodically. This meant that the app downloading took approximately 15 min instead of less than five, as it should have. Social media notifications also caused some interruptions to learning.

9. Affordances

Sarah and Jake both enjoyed the one co-operative app I recommended, Math Slide 1000 which enabled up to four players to join in one game.

> "There's this really cool one that Mrs Kendall did with Jake. You can have more players and you've got to do the maths." (Sarah, Interview 2)

Some RHS students only see their teacher for 2 h per week face to face, and even occasionally only once a week when the student lives very remotely. In my experience as a teacher in this context, I found my students unwilling to contact me to ask for support out of our contact hours despite my encouragement to do so. These factors made provision of suitable independent tasks extremely important. They needed to be at a level, which was achievable, yet challenging enough to be promoting learning without immediate teacher scaffolding.

I had wondered if the non-threatening feedback of an app would be a positive attribute of using the apps for mathematics to facilitate differentiated learning programs and there was some evidence of this during the observations such as when Jake was persevering with Kosmic Math HD as described earlier. However, the students did not seem to rate this sort of feedback any better or worse than teacher feedback.

> "If I was in class and had a maths worksheet that I couldn't understand, I'd just go and ask the teacher to explain. And if you're on the iPod on a maths app, most of them have a button with an i on it for information and I click that." (Jake, Interview 1)

In his second interview, Jake described the feedback that the apps gave him.

> Jake: If I got the question wrong it would just go mmm and I would go on to the next question, or I'd do it again until I get it right. Like on Pizza 1 I was seeing what happened if you get it wrong and it just keeps giving you more tries until you get it right.
> Helen: Do you find that sort of feedback helpful?
> Jake: Yeah . . . ish.

In her second interview, Amanda described the feedback the apps gave her as "Really helpful, some of them [with] learning more about math". When asked if it was easier to hear that from an app than a person, she replied, "No . . . not any different, just give me more confidence actually."

An affordance of the apps was their portability. Once the apps were downloaded, the devices did not need to be connected to the Internet. One family did not have Internet access for one of the weeks the students were supposed to be using the apps but the apps could still be accessed as they were already downloaded.

> When asked whether he could take his iPad places and not do it just at home, Jake replied, "Yes, cos it doesn't use Internet." (Jake, Interview 2)

Sarah and Amanda both mentioned using the apps in the car.

> "I did them at school as well, in the mornings and in the afternoons. I spread them across the day but I do them 15 min a day. In the car or something I still do it." (Sarah, Interview 2)
> "On road trips, in the car." (Amanda, Interview 2)

10. Conclusions

Although this was a small case study, it did reveal some illuminating data around the question of how apps for mobile devices influenced student engagement, when they were enrolled in a hospital school through facilitating differentiated learning programs. The themes that emerged in the results have informed conclusions and implications around conditions for positive engagement with apps at three levels of education; individual student aspects; pedagogical aspects and societal aspects. These aspects all need to be considered carefully when introducing apps for mobile devices into mathematics programs. Links will be made to the existing literature around this topic and the data collected. The strengths and limitations will be discussed and suggestions made for further research.

This research set out to investigate how apps for mobile devices influenced student engagement through facilitating differentiated learning. Was there a case for encouraging RHS students to use mathematics apps on their mobile devices as a means of providing engaging independent activities? The data showed that three of the four RHS students were engaged in using apps for mathematics and were keen to continue to use them. One student was not positively engaged in using the mathematics apps and her negative attitude towards mathematics was unchanged by introducing apps to her mathematics program. Although they did not appeal to her, she did recommend apps for mathematics for other RHS students. A number of conditions were identified as helping to establish an environment for apps to be an engaging part of the RHS mathematics program. Conditions that negatively affected engagement were also identified. The conditions for positive engagement in learning using apps fall into three levels with some overlap between them. Recommendations will be made at each level beginning with the student level.

The affordances of m-learning were evident in the students' interaction with the apps. The variety of apps appeared to facilitate differentiated learning. The affordances for learning offered by mobile devices of mobility, flexibility, ease of use, interactivity, fun, visualization, immediate feedback, realistic situations, simultaneous linking and risk-taking were illustrated in the data (Anthony and Walshaw, 2007 [32]; Calder, 2009 [62]; Ciampa, 2014 [54]; Melhuish Spencer et al., 2013 [30]; Moyer-Packenham and Westenskow, 2013 [29]; Mulligan and Mitchelmore, 2009) [31].

The students appreciated apps that facilitated differentiated learning. They enjoyed apps that helped scaffold them in their ZPD and were at the right level for them both academically and developmentally (Vygotsky, 1978) [37]. Conversely, they were bored by apps that were too easy or babyish and did not appeal to their interests or learning style. In the RHS context, where contact with the teacher and peers is limited, the apps were able to provide some interactive feedback and electronic scaffolding. As also noted by Calder (2009) [62] and Gee (2005) [52], some students displayed an appetite for risk-taking when using the apps. Despite their health concerns, the three enthusiastic students were willing to be challenged by material, which appeared to be at the upper end of their ZPD. The observations of the students using the apps showed the value of the immediate, correct feedback the apps gave. The students were able to adjust their thinking quickly and correct their errors. This was a marked improvement on the sheet of equations observed being completed incorrectly earlier when teaching at the RHS.

The variety of types of apps allowed learning to be differentiated which appeared to contribute to positive engagement. Some apps provided visual representations of mathematical structures, which have been shown to be helpful for learners of mathematics (Mulligan and Mitchelmore, 2009) [31]. One participant was engaged by the outer space themes of two of the apps he used which were chosen to appeal to his interests.

Realistic situations for applying mathematical knowledge are advantageous in learning mathematics (Anthony and Walshaw, 2007) [32]. The data demonstrated realistic situations in the form of playing games with family members and in the app *Math Slide 1000*, which used a variety of real-life objects to illustrate place-value. However, there were limited links to mathematics in real life contexts in the apps used. This would be something to investigate further. How can the affordances of mobile technologies such as cameras, and apps for activities such as foreign money exchange be harnessed to provide real-life contexts for mathematical thinking?

The affordance of mobility was evident in the data. Three of the students mentioned using their apps when they were away from home or school, particularly in the car. It was a benefit of the apps that once downloaded, it was not necessary to be connected to the Internet to access them. This affordance is particularly useful in the RHS context where students are likely to be completing their school tasks at a range of locations

Engagement

Three of the four students described the apps as fun. These comments indicated that they were enjoying their learning, which is an indicator of positive engagement (Attard, 2011 [50]; Ciampa, 2014 [30]; Gee, 2005 [52]). The individual participants had different preferences for which apps they found fun. Jake particularly enjoyed *Kosmic Math HD*, the game-type app that appealed to his interest in space and took the player on a mission to solve a puzzle by correctly solving mathematics equations. Sarah preferred worksheet type apps, as she called them. She found the satisfaction of making progress with her learning fun. She also appreciated the creativity and color of the apps. Jessica found using apps, "kind of fun". Her favorite was *Where's my water?* a colorful, puzzle type app. She enjoyed progressing through the levels of the app. The variation between the students' preferences supports the assertion that motivation is enhanced when students experience a measure of control and have opportunities to learn at their own pace (Ciampa, 2014) [30]. Those three students also found the apps that provided opportunities for interaction between students and families to be enjoyable. This illustrated the opportunities m-learning provides for connection and convergence (Melhuish and Falloon, 2010) [10]. Family support appeared to support the students' engagement in learning. This would be especially important if the RHS students were bedridden for extended periods of time.

Access to devices and technology to support their devices affected student engagement and has implications for implementing apps into students' programs. As found by Larkin (2014) [14], there was a range of cheap or free pedagogically sound apps for Apple and Android operating systems that could meet the criteria for effective apps for facilitating differentiated learning programs in mathematics, but it was time-consuming to identify them. In my experience, the apps for Apple devices appeared to be more consistent in quality but were also more expensive to purchase. However, the Windows phone had far less options and limited usefulness as a mobile device for supporting apps in a mathematics program. This may change in the future as more apps are developed. This leads to the importance of the teacher's role in providing a quality-learning program that utilizes apps for mobile devices.

The conditions for engagement of students outlined in the previous section inform pedagogical decisions teachers need to make when integrating apps for mobile devices into their mathematics programs. The TPACK framework can be applied as teachers combine their technological, pedagogical and content knowledge to choose effective learning tasks for their students (Koehler and Mishra, 2008, 2009) [63,64]. If the learning goal for the student is practicing basic number knowledge, there are many quality apps that can address this need in an engaging way compared to pen and paper. Teacher knowledge of the mathematical content knowledge, students' learning needs, interests and learning preferences assist the selection of appropriate apps.

Some students will require direct teaching of how to use particular apps. The student who was least engaged in this research was also the least confident with exploring the apps given to her. Teachers need to be careful not to exacerbate the digital divide by assuming students have experience and are comfortable working out how to use the apps simply because they are young (Haythornthwaite, 2007) [65].

11. Strengths and Limitations

As this was a case study of four students and one teacher in a particular context, it is not possible to generalize these findings to a broader context. This research aimed to present a snapshot of a particular group at a particular time and use this data to suggest points to consider, rather than to identify causal links. However, a case study adds to the broader body of knowledge. The honesty of the responses of the participants and rich data collected indicate that this was a valid method to use, especially in the RHS context where the students' health concerns require particular sensitivity in data collection methods. The implications outlined are particularly applicable to the RHS context, but may also have wider resonance. Nevertheless, a limitation of the study was that there were only four student participants. They were the only students at the hospital school of the appropriate age at the time the data was collected. Because attendance at the school is always in transition, it was possible that there might be no students there at that particular time or more than four. It was not possible to preset the number that would be referred and accepted into the school at any particular time.

Although care was taken not to influence the students' opinions of using apps in their mathematics programs, there was a power imbalance present and this may have inadvertently occurred. The fact that the teacher was willing to nominate and encourage her students to take part in the research may have signaled a positive attitude towards using apps in the RHS context. When data were collected, there were two adults present and one student. The three students who were very positive about their engagement may have been influenced by a willingness to please the adults, especially when completing the questionnaires. However, the negative responses from one student do indicate that the students felt safe enough to express both positive and negative opinions. The triangulation of data with student interviews, observations and teacher interview also helped mitigate these possible influences. Although the researcher had taught at the RHS previously, she did not know either the teacher or students prior to carrying out this research project. This meant observer bias was minimized as the students and teacher saw her as an interested observer rather than a colleague or teacher.

Only one student replied to the email half way through the three-week period. This removed another layer of data to analyze. As this study took place over three weeks, there was no opportunity to consider the long-term effects of using apps. The students may have lost interest in the apps once the initial novelty had worn off. This could be a focus of a future study.

12. Implications

Apps do appear to be an engaging means for some students, especially to practice number knowledge independently. They have the potential to be used to support other mathematical learning. They appear to have a place as a tool for learning alongside other traditional and e-learning methods such as websites but it is subject to thoughtful management to harness the affordances of apps for mobile devices. As this study involved a small number of students, it would be interesting to conduct a larger research study perhaps using this research design as a base to gather data on a larger range of students of different ages, cultures and abilities. It would be interesting to investigate whether positive engagement with apps corresponds with improvement in mathematical achievement or knowledge. An area for further study in the RHS context would be to look at how to use mobile devices to stimulate and promote mathematical thinking and communication. It is important for these students, who can often be isolated physically to still belong to learning communities (Ministry of Education, 2007) [66]. Mobile devices may present some opportunities for RHS teachers to facilitate online cooperative learning communities. Another opportunity for further study in the RHS context would be to investigate using mobile devices to support literacy learning through apps or using mobile devices to download texts.

This case study has shown that, for some students in the RHS context, using apps for mobile devices had a positive influence on student engagement. Mobility, fun, colorful visualizations, immediate feedback, encouragement of risk-taking and opportunities for collaboration and competition with peers and family members were affordances of apps identified as positively influencing student engagement. The capability of apps to facilitate differentiated learning programs through catering to different levels and learning preferences was a benefit of the apps. The control students had to choose apps, select levels to support their learning goals and work through the apps at their own pace appeared to enhance their engagement. These findings also suggest that apps may have benefits for other groups of students working in isolated situations or with intermittent attendance.

Difficulties with technical aspects, unsuitable app selection, lack of funds to buy full versions of apps and low student motivation impacted negatively on student engagement with the apps. These issues should be considered when implementing apps into a learning program. With the adoption of a flexible, collaborative approach and support at institutional and community level, apps have the potential to be another useful tool.

While there were some limitations with the scope of the research and negative elements around introducing apps into the mathematics program, the data and literature indicated that using apps for mobile devices can have a positive influence on student engagement and help to facilitate differentiated learning programs in the RHS context.

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