

Exploring the Use of Mathematics Apps in the Elementary School Classroom

by

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Abstract

Many reports indicate that students have difficulty in mathematics (Carr, 2012; Hinton, 2014; National Assessment of Educational Progress, 2013). Some evidence suggests that technology can help improve student performance in the field (Boogart et al., 2014; Riconscente, 2013). This study investigates how the use of digital mathematics applications (apps) in a grade 2/3 class could affect student attitudes and academic performance by assessing and comparing the quality of different apps. Five specific apps, Thinking Blocks, Sushi Monster, Math Tappers, Prodigy, and Show Me, were carefully selected based on set criteria. This study used a mixed methodology, including survey data, open-ended questions, interviews, and performance tests. Twenty students, including eleven grade 2 (six males, five females) and nine grade 3 (five males, four females), participated in this study. The results indicated the importance of focusing on specific types of mathematics apps rather than focusing on the technology itself. The students enjoyed the challenge of solving math problems and believed this helped them learn. The game-based apps, especially the micro-world type app, were some of the favourite apps that the students selected because it engaged them, provided positive feedback, and they were able to create customised characters. The students preferred to use fun and easy apps rather than those that were more complicated to use. Students' mathematics performance significantly increased after the use of math apps, but other factors, such as the quality of the teacher's instruction, additional use of mathematics manipulatives, and support from home could have influenced the results.

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1 Introduction

1.1 Overview

According to Pew Research Center, the number of tablet owners in the United States increased from 4% in 2010 to 45% in 2015 (Keengwe, 2013). Due to increased use, researchers have conducted a number of studies on the impact of tablet use in elementary to post-secondary education settings. However, the results are conflicting. A number of studies have noted many of benefits regarding tablet use, including instant feedback (e.g., Bhanot, 2009; Clark & Luckin, 2013), easy adoption of cross-curricular activities (e.g., Alon et al., 2015a; Boogart et al., 2014), differentiated instruction (e.g., Beck-Hill & Rosen, 2012) and gains in academic achievement (e.g., Alon et al., 2015a, 2015b; Asam, Gallegos, Trussell & Zhang, 2015). Others researchers have argued that there are several challenges at all levels when using tablets in school, including distracting advertisements (e.g., Alsufi, 2014; Block et al., 2014), difficulty monitoring student progress (e.g., Falloon, 2014), and limited improvement in academic achievement (e.g., Carr, 2012; Cheung & Salvin, 2011; Hall, 2015).

According to the National Assessment of Educational Progress (2013) in the United States, more than 376,000 grade 4 students and 341,000 grade 8 students were assessed in mathematics in 2013, and the average score was only one point higher than the 2011 result. In general, student performances in mathematics are below average in elementary schools in the United States despite the *No Child Left Behind Act* (Carr, 2012). Moreover, in Ontario, the Education Quality and Accountability Office test scores for math have

continued to decline over the past five years (Hinton, 2014). Mathematics, then, is one possible subject area that could benefit from the use of technology.

Some studies have reported a significant improvement in mathematics performance when the tablet is used (Boogart et al., 2014; Riconscente, 2013). Boogart et al. (2014) studied 1:1 tablet use in mathematics in the United States and found that the performance of 55 % of kindergarten to grade 4 students increased when tablets were used. A case study by Riconscente (2013) indicated that tablet use increased grade 4 students' knowledge of fractions by 10 to 15 % in mathematics classes. Nevertheless, relatively limited research has been conducted on the impact of the use of technology in elementary mathematics classes.

1.2 Gaps and Problem Areas

A few gaps were noted in the literature on tablet use, including a limited focus on the use of apps in mathematics class in primary school (up to grade 3) environments. Some studies focused on teacher's perception of how students use tablets in classrooms (Boogart et al., 2014; Bush & Cameron, 2011; Garwood, 2013; Johnson, 2013). Many case studies presented student attitudes towards using tablets in classes (Alon et al., 2015d; Bloemsma, 2013; Brummel et al., 2013; Harris, 2015), yet there is less focus on any analysis of specific apps. Thus, more in-depth understanding of the student perspective when using specific mathematics apps is needed. In addition, most studies focused on literacy, with relatively few studies on the use of tablets in mathematics classes (Bebell, Doris & Muir, 2013; Bush & Cameron, 2011; Falloon, 2014; Garwood, 2013; Howard & Zimmerman, 2013; Johnson, 2013; Kocak, 2015). Finally, many studies have been conducted in

secondary schools or higher education institutions, but not at the primary level (Alon et al., 2015d; Bloemsma, 2013; Bush & Cameron, 2011; Choi et al., 2012; Galligan et al., 2010; Isabwe, 2012; Kaciupski, 2013; Kocak, 2015). Therefore, research on the impact of apps on elementary school students in mathematics is needed.

1.3 Purpose

The current study investigates the use of mathematics apps in a grade 2/3 class. The goal of this study is to examine student attitudes toward, and performance with, a broad range of systematically reviewed mathematics apps.

2 Literature Review

2.1 Overview

A review of the literature from 2001 to 2016 on tablet use in the classroom revealed five main research themes: student attitudes toward tablets (general, motivation, ease of use), student behaviour with tablets (collaboration, communication, distraction), impact on student learning (general, performance, differentiation), characteristics of apps used with tablets, and technical problems.

2.2 Students Attitudes Toward Tablets

2.2.1 General Attitudes

A number of studies indicated that students had positive attitudes toward using tablets (Allouch, 2014; Bloemsma, 2013; Heinrich, 2012; Kaciupski, 2013; Kocak, 2015; Kyanka-Maggart, 2013; Riconscente, 2013). Primary school students who participated in a pilot program expressed that they liked working with tablets and had fun doing so (Allouch, 2014). A qualitative study conducted on the attitudes of secondary school students towards the use of iPads in the classroom reported that students were interested in, and enjoyed learning, with iPads (Bloemsma, 2013). Ninety percent of the students in Heinrich's (2012) study of 960 grade 6-13 students noted that they were happy using iPads in their learning. Kaciupski's (2013) study also indicated that out of 89 secondary school students, 71% reported that they felt that iPads were extremely or very useful and resulted in a positive learning experience in mathematics class. Kocak's (2015) qualitative case study with secondary school students reported that the students liked using tablets and

they wanted to continue to use them. A mixed method study of 22 grade 5-6 students revealed that the students liked working with iPads rather than the traditional pen and paper approach when solving mathematics problems (Kyanka-Maggart, 2013). Finally, qualitative research with grade 4 students in mathematics classes by Riconscente (2014) indicated that students liked using tablets when solving fraction problems. Overall, the students who participated in the above studies regarded the use of tablets in the mathematics classroom positively.

2.2.1.1 Positive Impact

Nine studies report that the use of tablets has a positive impact on student motivation (Boggart et al., 2014; Ciampa, 2014; Clark & Luckin, 2013; Hall, 2015; Heinrich, 2012; Howard & Zimmerman, 2013; Kocak, 2015; Kyanka-Maggart, 2013; Riconscente, 2013). A mixed method case study at a kindergarten to grade 4 elementary school in the United States noted that 84% of students agreed that iPad use improved student motivation and 58% indicated that students worked harder on their assignments (Boogart et al., 2014). According to Ciampa's (2014) qualitative case study on the motivational impact of mobile device learning, 24 grade 6 students identified that they felt motivated by collaboration and self-directed, authentic learning activities on tablets. Clark and Luckin (2013) reported that iPad use created a personal learning experience for students, which led to a highly motivational experience (Clark & Luckin, 2013). Hall (2015) conducted a mixed method study with 124 grade 4 students in mathematics classes and compared the effect on both traditional (pen and paper) and tech-based learning environments. The study revealed that students were more motivated when they practised mathematics while

using technology. In addition, Heinrich's (2012) quantitative study on grade 6-13 student attitudes toward using iPads in the United Kingdom reported that they were more motivated when using iPads. Howard and Zimmerman (2013) added that introverted students were more actively involved when using iPads. Kocak's (2015) observed that secondary school students were motivated when using tablets in mathematics' class. Kyanka-Maggart's (2013) qualitative study of 22 elementary school students indicated that iPads were a motivating factor for students and had a positive influence on students' perception and motivation in the mathematics. Finally, Riconscente's (2013) qualitative study with 122 grade 4 students in the mathematics classes noted that student motivation increased when using tablets to solve mathematics problems.

2.2.1.2 Mixed Impact

Two studies reported that there were both positive and negative impacts on using tablets (Fuchs, 2013; Swicegood, 2015). Fuchs's (2013) mixed methods study reported that grade 7 students were motivated when using the iPad for geometry units, but some students mentioned that they could not make connections between learning and the apps (Fuchs, 2013). Moreover, Swicegood's (2015) study with 40 grade 2 students in mathematics classes revealed that half of the students preferred to use the iPads while the other half preferred paper and pencil.

2.2.1.3 No Impact

Two studies noted that there was no impact on student motivation when tablets were used (Harris, 2015; Singer, 2015). Harris (2015) examined four grade 3 students in need of extra support in mathematics and focused on attitudes and the impact of tablets.

The result indicated that student attitudes and motivation toward mathematics did not change after using iPads (Harris, 2015). Moreover, Singer's (2015) case study on tablet use in a grade 3 mathematics class noted that there was no significant difference between student attitudes when using iPads versus when the students did not use iPads.

2.2.2 Ease of Use

Five studies noted that students were able to adapt easily to tablet use in a classroom setting (Allouch et al., 2014; Bush & Cameron, 2011; Craft et al., 2013; Kyanka-Maggart, 2013; Tsuei, 2012). Allouch et al.'s (2014) qualitative case study of 139 primary students indicated that most students found the tablet PC was easy to use. A qualitative study by Bush and Cameron (2011), which focused on the effectiveness of the iPad in the academic environment with 35 postgraduate students, revealed that 84% of the students believed the iPad was easy to use. Craft et al. (2013) reported that primary and secondary school students rapidly learned the tablet interface and navigated it without difficulty. A mixed method case study by Kyanka-Maggart (2013) noted that elementary school students were able to easily access resources when using iPads. Finally, Tsuei's (2012) case study noted that grade 5 students felt it was very easy to use tablets.

2.3 Students Behaviours with Tablets

2.3.1 Collaborative Learning

The use of tablets enriches student learning experience and creates collaborative opportunities with peers (Alon et al, 2015d; Beck-Hill & Rosen, 2012; Block et al., 2014; Bloemsma, 2013; Brummel, Greer, Jackson & Pollet, 2013; Garwood, 2013; Heinrich, 2012; Isabwe, 2012; Keengwe, 2013). Alon et al. (2015d) noted that iPad use of secondary school

students created a collaborative learning environment. Beck-Hill and Rosen's (2012) study of 476 elementary school students reported that one-to-one tablet initiatives spawned a collaborative and engaging learning experience for students. Block et al.'s (2014) qualitative study reported that grade 6 and 9 students experienced a positive impact on their learning and collaboration with one another when using tablets. A case study on iPad use with 14 secondary school students noted that those who had access to technology had more collaborative opportunities than those who did not (Bloemsma, 2013). Brummel et al.'s (2013) mixed methods study with 53 elementary school students using tablets added that boys collaborated with each other by helping their peers to understand and learn mathematics materials. Garwood's (2013) observed that grade 3-6 students who had access to iPads had a more collaborative learning experience than students who did not. Heinrich's (2012) quantitative study with 960 grade 6-13 students also reported that iPad use helped students to collaborate easily. Isabwe's (2012) study noted that students using iPads collaborated more on problem solving (Isabwe, 2012). Finally, Keengwe (2013) study noted that grade 3 students helped each other solve problems when using iPads in mathematics class.

2.3.2 Communication

The use of tablets can increase communication amongst students and teachers (Alon et al., 2015a; Beck-Hill & Rosen, 2012; Clark & Luckin, 2013; Garwood, 2013; Howard & Zimmerman, 2013). Beck-Hill and Rosen's (2012) mixed methods study with elementary school students indicated that one-to-one computing programs with tablets increased the interaction between students and teachers. Clark and Luckin (2013) noted that the use of

iPads increased communication between parents and teachers, and teachers and students. Garwood's (2013) mixed method study with grade 3-6 students reported that when iPads were used, the teacher became a facilitator rather than a "knowledge dispenser," and the students started to take control of their learning. Finally, a case study on iPad use at a K-12 school, which investigated students' engagement and motivation levels, reported that the iPad experience created a better connection between teachers and students (Howard & Zimmerman, 2013).

2.3.3 Distraction with Tablets

A number of research studies suggest that tablets can be distracting (Alon et al., 2015a; Alsufi, 2014; Block et al., 2014; Bloemsma, 2013; Bush & Cameron, 2011). Alon et al.'s (2015a) study reported that students were distracted by other functions on tablets and went off task, causing class management issues. In addition, Alsufi's (2014) quantitative study regarding iPad use in the classroom evaluated 250 K-12 classrooms teachers indicated that students were distracted by easy access to social media, such as Facebook, during the instruction time. Similarly, grade 6 and 9 students, when using iPads, were distracted by easy access to the web (Block et al., 2014). Bloemsma's (2013) observed, in a case study, that students became distracted when the task was not engaging. Bush and Cameron (2011), in a study of 35 post-graduate students' use of tablets, claimed that 25% of the students found reading from a tablet screen distracting and preferred to read from printed material.

2.4 Learning and Tablet Use

2.4.1 General Impact on Learning

Researchers have reported mixed results on student learning when using tablets for mathematics. Five studies reported that the use of tablets had a positive impact on their learning (Carr, 2012; Donehower et al., 2013; Galligan et al., 2010; Johnson, 2013; Keengwe, 2013). Carr's (2012) quantitative study with 104 grade 5 mathematics students revealed that tablets encouraged higher order thinking skills and reduced achievement gaps. Donehower et al.'s (2013) mixed methods case study examined the impact of iPad use on ten students with disabilities. The study reported that tablets helped foster basic mathematics skills for students. Galligan et al.'s (2013) study focused on the use of tablet PCs at the university level and indicated that technology helped to improve students' learning. Johnson's (2013) mixed method case study noted that the use of iPads supported elementary students with special needs and improved their learning outcomes. Lastly, Keengwe's (2013) case study focused on the advantages and challenges of iPad use in mathematics and language classes with 22 grade 3 students. The study indicated that the students were able to create a student-centred learning environment, where they could control their learning.

In contrast, two studies reported that students did not find tablets helpful in a mathematics class (Kaciupski, 2013; Singer, 2015). Kaciupski's (2013) reported that secondary school students (n=80) perceptions of learning when using iPad technology decreased within a year. Singer (2015) performed a qualitative study on the attitudes of 233 grade 3 elementary school students who used tablets in mathematics class. In this

study, the students indicated that tablets were not helpful in mathematics class (Singer, 2015).

2.4.2 Performance

Eighteen studies indicated that the use of tablets helped academic achievement (Asam, Gallegos, Trussel & Zhang, 2015; Bebell, Dorris & Muir, 2012; Boogart et al., 2014; Brummel et al., 2013; Donehower et al., 2013; Garwood, 2013; Harris, 2015; Herro, 2012; Keengwe, 2013; Pitchford, 2014; Riconscente, 2013; Swicegood, 2015; Tabor, 2014; Trujillo et al., 2013). Assam et al. (2013) reported that post-test results improved significantly and learning gaps for at-risk students decreased when grade 4 students (n=18) used mathematical apps. Bebell (2012) observed that kindergarten students (n=288) who had access to iPads had significant improvements in their learning compared to those who did not have access. Furthermore, a mixed method case study at a K- grade 4 elementary school in the United States noted that 93% of teachers believed that handheld technology had a positive impact on students' learning (Boogart et al., 2014). Brummel et al. (2013) conducted a mixed methods study on the use of tablet technology in mathematics classes at an elementary school and reported that boys in the experimental group improved their mathematical achievement. Donehower et al. (2013) conducted a mixed methods study on the impact of iPad use in mathematics with ten elementary special needs students and indicated that the students were able to provide correct answers while using tablets. Similarly, Garwood (2013) identified that the engagement and achievement levels of grade 3-6 students increased when using iPads in mathematics. Harris (2015) conducted a study with four grade 3 students who needed extra support in mathematics. The study revealed that they were faster, more accurate, and attempted more problems

after using tablets. In addition, the use of iPad games helped them with accuracy and speed in a single digit multiplication (Harris, 2015). Herro (2012) conducted a case study with 87 grade 3 students in mathematics classes and focused on the impact of iPad use. The results indicated that those students who were in Mobile Learning Intervention correctly answered more questions and outperformed on their test compared to the students in the control group. Keengwe (2013) examined a study with grade 3 students on iPad integration and noted that post-academic performance significantly improved. In addition, Pitchford (2014) conducted a quantitative study with 400 grade 3 students on student attitudes and the impact of tablet use, especially with the Euro Talk Tablet app. The result of the study indicated that over eight weeks, 78% of low achievers who received tablet intervention improved their mathematics ability. Riconscente's (2013) quantitative study with grade 4 students in mathematics classes noted that the use of the iPad app, Motion Math (fraction game), improved students' fraction knowledge and attitude by 10-15%. Similarly, Swicegood (2015) reported that iPad use in mathematics classes during a four-month period improved the quiz results of 40 grade 2 students. Tabor (2014) also reported on student performance in mathematics by conducting pre and post-tests after use of iPad and Android devices, and the results indicated that students improved their mathematics score by 70%. Finally, Trujillo et al. (2013) conducted a mixed methods case study with 480 elementary school students on attitudes and performance while using a Mathematics Snacks app (the app uses animation and support materials to teach mathematics concepts). The result indicated a higher performance on a mathematics test (Trujillo, 2013).

Although many studies reported that there was a positive impact on student performances when using tablets, five studies indicated that there was no significant academic impact on student learning (Carr, 2012; Hall, 2015; Leidman et al., 2014; Singer, 2015). Carr (2012) reported that there was no significant difference in math scores between the grade 5 students (n=56) who had access to iPads and students who did not. Hall's (2015) study compared the differences between traditional and tech-based practice and its effect on grade 4 student achievement and motivation levels. The study claimed that the use of tablets did not lead to greater achievement in mathematics. Leidman et al. (2014) reported that there was no significant improvement in achievements when comparing grade 2 students (n=131) who participated in the iPad intervention program to those who did not. Finally, Singer's (2015) mixed methods study with 233 grade 3 students noted that there were not many differences between students who used iPads and students who were taught in a traditional mathematics class.

2.4.3 Differentiation

Six studies reported that tablets enhanced student differentiated learning experiences (Alon et al., 2015a, 2015c; Beck-Hill & Rosen, 2012; Boogart et al., 2014; Singer, 2015; Tabor, 2014). Alon et al. (2015a) indicated that the use of iPads promoted student engagement because it offered individualised, interactive, and experiential learning. In another study, Alon et al. (2015c) noted that tablets offered a variety of activities to primary school students. Beck-Hill and Rosen's (2012) mixed method study with 476 elementary school students reported that one-to-one computing programs using tablets promoted a differentiated learning experience for students. Boogart et al. (2014)

observed that elementary school students (n=17) received customised assignments that catered to their personal strengths and abilities when tablets were used. Singer's (2015) mixed method study noted that the use of tablets accommodated grade 3 students (n=233) different academic levels and needs. Finally, Tabor (2014) reported from a quantitative study with an elementary mathematics class that a personalised assignment on tablets helped to build students' critical thinking skills.

2.5 Characteristics of Apps Used with Tablets

2.5.1 Game-Based

Game-based learning occurs when students are learning and practising concepts while playing games (Finn, Ketamo, Kiili & Koivisto, 2014; Kyanka-Maggart, 2013; Riconscente, 2013). Apps for tablets can create behavioural, emotional and cognitive student engagement while playing games (Blumenfeld et al., 2004). Several studies identified that students were actively engaged in activities when working with game-based apps (Finn et al., 2014; Kyanka-Maggart, 2013; Riconscente, 2013). A qualitative study with 153 primary students on tablet-based games indicated that mathematics games stimulated engagement in learning (Finn et al., 2014). Moreover, Kyanka-Maggart's (2013) study on elementary school students indicated that game apps encouraged students to aim for higher levels of learning. Finally, Riconscente's (2013) study reported that mathematics confidence level and knowledge of grade 4 students (n=122) increased when using game-based iPad apps. (Riconscente, 2013)

2.5.2 Feedback

Feedback is an important feature for students, and it plays an active role in student engagement and confidence levels (Bhanot, 2009; Isabwe, 2012; Swicegood, 2015). Seven studies noted a positive impact from the immediate feedback provided by tablet apps (Brummel et al., 2013; Keengwe, 2013; Kyanka-Maggart, 2013; Riconscente, 2013; Tabor, 2014). Brummel et al.'s (2013) mixed methods case study on tablets in the mathematics class in an elementary school indicated that immediate feedback led to an increase in students' mathematics performance. Keengwe's (2013) study examined the advantages and challenges of integrating iPads into grade 3 classes and reported that students found immediate feedback from tablets was helpful for learning. Another qualitative case study conducted on elementary school students by Kyanka-Maggart (2013) reported that immediate feedback pushed students to see what they could do when teachers were not available. Riconscente's (2013) quantitative study with grade 4 students in mathematics classes indicated that iPad apps provided instant feedback to students, which helped to scaffold concepts that the students were learning. Lastly, Tabor (2014) reported that immediate feedback from mathematics apps helped to engage Junior Kindergarten to grade 4 students (n=97).

Three studies indicated that feedback features of apps were not effective and needed improvements (Finn et al., 2014; Howard & Zimmerman, 2013). Finn et al.'s (2014) qualitative study examined primary students' experience with tablet based mathematics games. The study reported that consistent, detailed feedback is needed to maintain students' engagement level. Moreover, a case study in mathematics classes at an elementary school indicated that the students had difficulty completing tests on iPads and

that they preferred the traditional way of assessment using paper and pencil (Howard & Zimmerman, 2013).

2.6 Technical Problems

Since tablets are relatively new, many technical problems needed to be resolved to enhance students learning experience (Alon et al., 2015b). At least five technological challenges associated with tablet use emerged from the literature, including internet access, storage space, internet safety and security, pop-up advertisements, and software issues (Allouch et al., 2014; Alon et al., 2015a; Alon et al., 2015b; Isabwe, 2012; Keengwe, 2013; Kocak, 2015).

In several studies, limited Internet access disrupted the flow of lessons (Allouch et al., 2014; Anderson & Hur, 2013; Isabwe, 2012; Keengwe, 2013; Kocak, 2015). In addition, students had limited storage space and could not save their work (Allouch et al., 2014; Alon et al., 2015a, 2015b). Internet safety and security was another problem when students were using iPads, as they did not have a set of rules or protocols to deal with technical challenges (Alon et al., 2015a, 2015b). Pop-up advertisement, which accompanies free apps, were problematic because they interrupted student learning (Anderson & Hur, 2013; Keengwe, 2013). Lastly, software glitches, on occasion, disturbed the students' learning experience (Alsufi, 2014; Kocka, 2015)

2.7 Limitations and Gaps in Previous Research

Previous research identified two significant limitations that focused on tablets in educational settings: lack of focus on specific app studies and limited focus on primary students.

Although many studies focused on general attitudes in mathematics and tablet use, a few studies focused on systemic analyses of mathematics apps (Murray 2011; Riconscente, 2013). Therefore, further studies need to be conducted on selected apps and an analysis of how students perceive the apps. In addition, the quality of apps needs to be identified through comparison between apps.

As well, a number of studies on tablets were conducted in junior to post-secondary institutions, with only 8.5% of the studies carried out at the primary level (Allouch et al., 2014; Alon et al., 2015c; Boogart et al., 2014; Harris, 2015; Keengwe, 2013; Leidman et al., 2013; Singer, 2015; Swicegood; 2015). In addition, many research studies focus on student attitudes towards learning with tablets among more senior levels, with less focus on primary students. In the few studies that were conducted with primary students, only two focused on the attitudes of primary students (Singer, 2015; Swicegood; 2015).

Many case studies described the attitudes of students when learning using tablets. Future studies will require more focus on primary students in the mathematics field, with a particular focus on apps, and the application of triangulation when collecting data. The current research study will address these items.

2.8 Research Questions

1. What are the attitudes of grade 2/3 students toward using mathematics apps in a class?
2. What is the impact of the use of mathematics apps on elementary students' performance?

3 Method

3.1 Design Philosophy

The primary goal of this study was to investigate the impact of tablet use on elementary school students in mathematics' classrooms. In particular, the study investigated attitudes toward tablet use and their impact on students' academic performance. Many possible variables could influence tablet use, including the students' prior knowledge of mathematics concepts, the quality of the teacher's instruction, the students' engagement level in the classroom, and any extra support that the students had from home. To obtain the most accurate results, a holistic understanding of the students' responses and behaviour was necessary.

Pragmatism is a philosophical worldview that supports this study's research method. Rossman and Wilson (1985) indicated that pragmatism involves using a variety of approaches to understand the problem rather than focusing on research methods. Pragmatism uses mixed methods research to understand a research problem better (Creswell, 2014) and increase the reliability of the data through triangulation (Maxwell, 2005). For this research, an explanatory sequential mixed method was used, whereby quantitative results are further explained with qualitative data. Specifically, a survey,

open-ended responses, interviews and pre and post-test scores were used to gather data about students' attitudes regarding tablet use, and the impact that use had on learning (Figure 1).

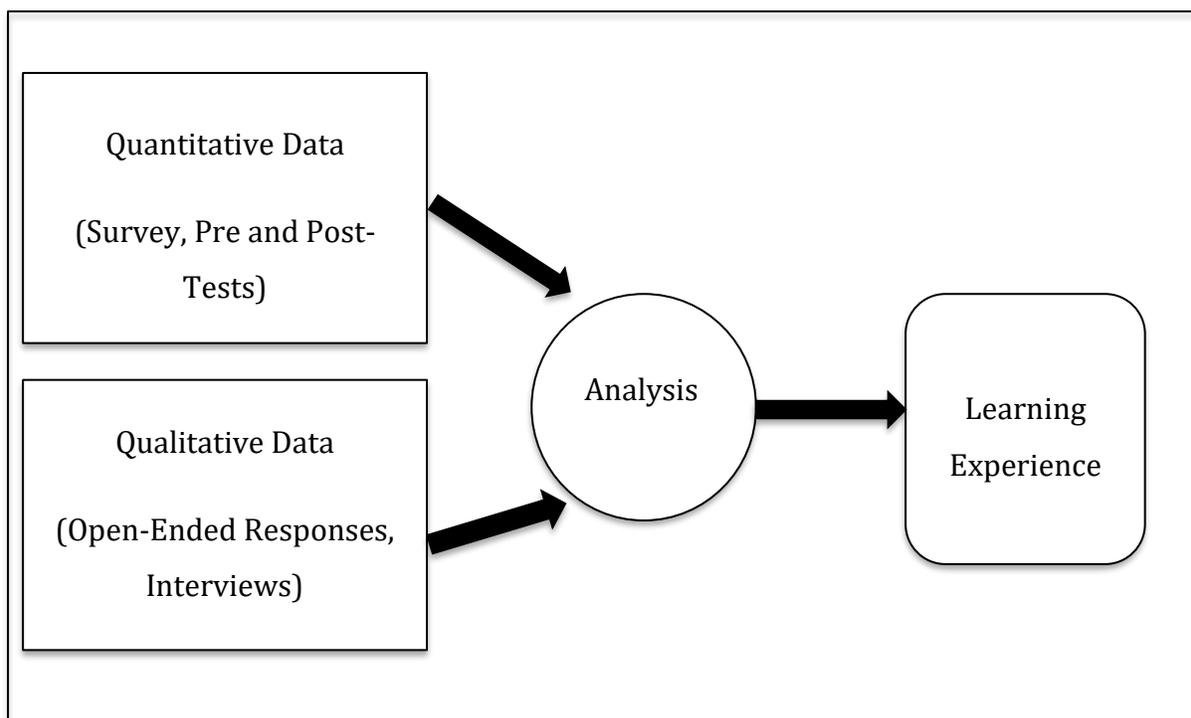


Figure 1 – Student Learning Experience – Mixed Method Design

With regards to the quantitative data, I assessed student attitudes about using tablets to learn mathematics through a survey. Pre- and post-tests helped to investigate and collect data about learning performance over a short period (Aagaard, Langenbach & Vaughn, 1994).

For the qualitative data, I used open-ended responses from the survey and interviews. These open-ended responses helped collect information about tablet use and what students liked and did not like about the process. The interview, which is a common strategy used in collecting qualitative data (Crabtree & DiCicco-Bloom, 2006), was another

method that helped to analyse the students' perceptions of tablet use in more depth.

3.2 Overview

Although both qualitative and quantitative data were collected in some studies, (Beck-Hill & Rosen, 2012; Brummel et al., 2013; Fuchs, 2013; Garwood, 2013; Hall, 2015), no studies used triangulation. Triangulation would include a pre- and post-test, survey and interview data, which would ensure the quality of the study's result. The idea of triangulation is significant to this study because pre- and post-test results are supported by survey and interview data, which will validate the results of the study, and will reduce the bias of the result.

This study addressed some limitations and gaps reported from previous studies including:

- focusing on the use of mathematics applications in an elementary school setting;
- collecting data from multiple sources (e.g., survey, interviews, pre and post-tests);
- and
- examining student performance.

3.3 Participants

3.3.1 Students

The sample consisted of 20 elementary school students between seven and nine years old (11 males, nine females) enrolled in a grade 2/3 split class. One student was on an Individualised Education Plan (IEP), and there were no English Language Learners.

The students lived in a city in Southern Ontario, Canada, with a population of about one million people. The average family income for parents in the school district area was approximately \$150,000. The school population was about 400 students with 6% classified as English Language Learners, and 16% of students with special needs (Fraser Institute, 2016).

3.3.2 Teaching Context

The teacher in this study had taught in an elementary school setting for four years. Although this was her first time teaching a grade 2/3 split class, she previously taught grade 3 students. She noted that she was comfortable using technology in her classroom, but that technology was not readily accessible. She had a positive attitude towards using new technology in her mathematics class, and she believed that it would engage her students. The classroom had a laptop, an LCD projector, a smart document camera, and Internet access. Tablets could be booked for use in the classroom, but only 30 iPads were available for the entire school, so accessibility was sometimes an issue. The teacher commented that while she did not work in a technology-based school, she believed support was available.

Since the teacher was teaching a split class, she usually divided the students into two grade-specific groups and assigned an independent task to one group while she was teaching a lesson to the other group. She often started the mathematics class with a warm-up question related to the topic that she was covering. In addition to tablets, students also used mathematics manipulatives, textbooks, and worksheets during class. An Education

Assistant (EA) was available twice a week to support students who required extra assistance.

3.4 Data Collection

3.4.1 Overview

A mixed methods approach was used in this study. Specifically, three data collection tools were used: surveys, interviews, and pre- and post-tests. I used a Likert survey to assess the students' attitudes toward using specific software tools on the tablet. In addition, I interviewed randomly selected students to establish an in-depth understanding of students' attitudes. Lastly, I measured performance using pre- and post-tests. Table 1 links the two research questions of this study with the data collection tools.

Table 1 – Overview of Data Collection Tools

Research Question	Data Collected	Appendix
1. What are attitudes of grade 2 and 3 students toward using tablets in Mathematics class?	Likert Questions Open-ended questions Interview with selected students	Appendix C Appendix E
2. What is the impact of the tablet use on elementary students' performance?	Pre- and Post-Tests	Appendix D

3.4.2 Survey

3.4.2.1 Demographic Data

The first three survey questions identified student gender, grade level, and the year of their birth. Demographic data was limited to three variables to keep student identity anonymous.

3.4.2.2 Attitudes Toward Apps

A Likert-scale, consisting of five items ranging from strongly disagree to strongly agree, was used to measure student attitudes toward using iPad apps in mathematics class. The students completed the Likert-scale questionnaire to determine their perceptions of usability, how much they learned, and how engaged they were when using iPad apps. These survey questions were written to be simple and easily understood by younger students (Appendix C). Each app was used in a class for at least four to five periods (each period is sixty minutes long). The survey questions were based on learning object scales developed by Kay and Knaack (2009) and Kay (2011, 2013) and consisted of three major themes: learning, quality, and engagement. The sample population in this study was much younger, so the vocabulary was modified accordingly. At the end of the survey, two open-ended questions were asked to assess what students liked and disliked about using the mathematics apps (Appendix C).

3.4.3 Interview

Six randomly selected students agreed to participate in the interview, and consent was obtained from their parents. They were interviewed about the mathematics' apps they used on the iPads (Appendix E). The students were asked about what they explored,

whether the use of iPads was helpful and whether they experienced any problems. Each audio-recorded interview took about 10 to 15 minutes to complete.

3.4.4 Mathematics Knowledge Pre-and Post-Tests

A pre-test (Appendix D) was conducted at the beginning of the study just before the start of the Number Sense unit. The grade 2 and 3 students completed a similar test format, but with different curriculum expectations. The grade 2 curriculum focused on one and two-digit addition and subtraction skills, and the grade 3 curriculum focused on two and three-digit addition and subtraction skills. The test consisted of simple adding and subtracting, estimating, and problem-solving questions. The post-test was virtually identical to the pre-tests except for a change in numbers.

3.5 Procedure

3.5.1 Overview

Table 2 provides the procedure and timing for each step in this study.

Table 2 – Overview of the Procedure

Step	Procedure	Time
1	The students and parents completed consent forms.	Prior to study
2	The students completed a pre-test on the Number Sense unit.	Day 1
3	The teacher taught an addition lesson and introduced the Math Tapper app.	Day 2
4	The students used the Math Tapper app to practice an addition skill with 2 digits during class time.	Day 2-5
5	The students completed the Math Tapper survey.	Day 5
6	The teacher taught a subtraction lesson.	Day 6

7	The teacher introduced the Sushi Monster app, and the students used the app to practice addition and subtraction skills with 2 and 3 digits.	Day 6- 10
8	The students completed the Sushi Monster survey.	Day 10
9	The teacher taught word problem lesson and introduced the Thinking Block app.	Day 11
10	The students used the Thinking Block app to practice word problems during class time.	Day 11- 15
11	The students completed the Thinking Block survey.	Day 15
12	The teacher introduced the Show Me app to present students' work.	Day 16
13	The students used the Show Me app during class time.	Day 16-20
14	The students completed the Show Me survey.	Day 20
15	The teacher introduced the Prodigy app, and the students used the app.	Day 21
16	The students used Prodigy, the game-based app, during class time to practice all the skills.	Day 22-25
17	The students completed the Prodigy survey.	Day 25
18	The students completed a post-test.	Day 26
19	Selected students were interviewed.	Day 27

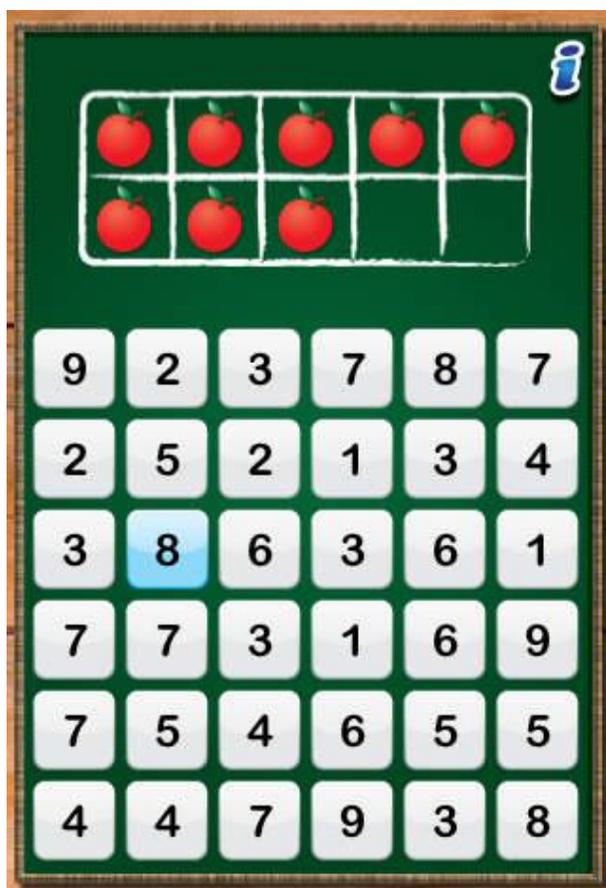
3.5.2 Description of Apps Use

3.5.2.1 Math Tappers

Math Tappers (Figure 1) helps students to practice basic addition and subtraction skills by choosing two numbers that total 100. It encourages students to improve their recall speed. Students can choose between two different mode. The first mode uses a grid of apples and the apples disappear as students choose a number. The goal of this app is to

select a pair of numbers that equal the total sum. The second mode uses a part-whole model, where only numbers are shown to practice addition and subtraction skills.

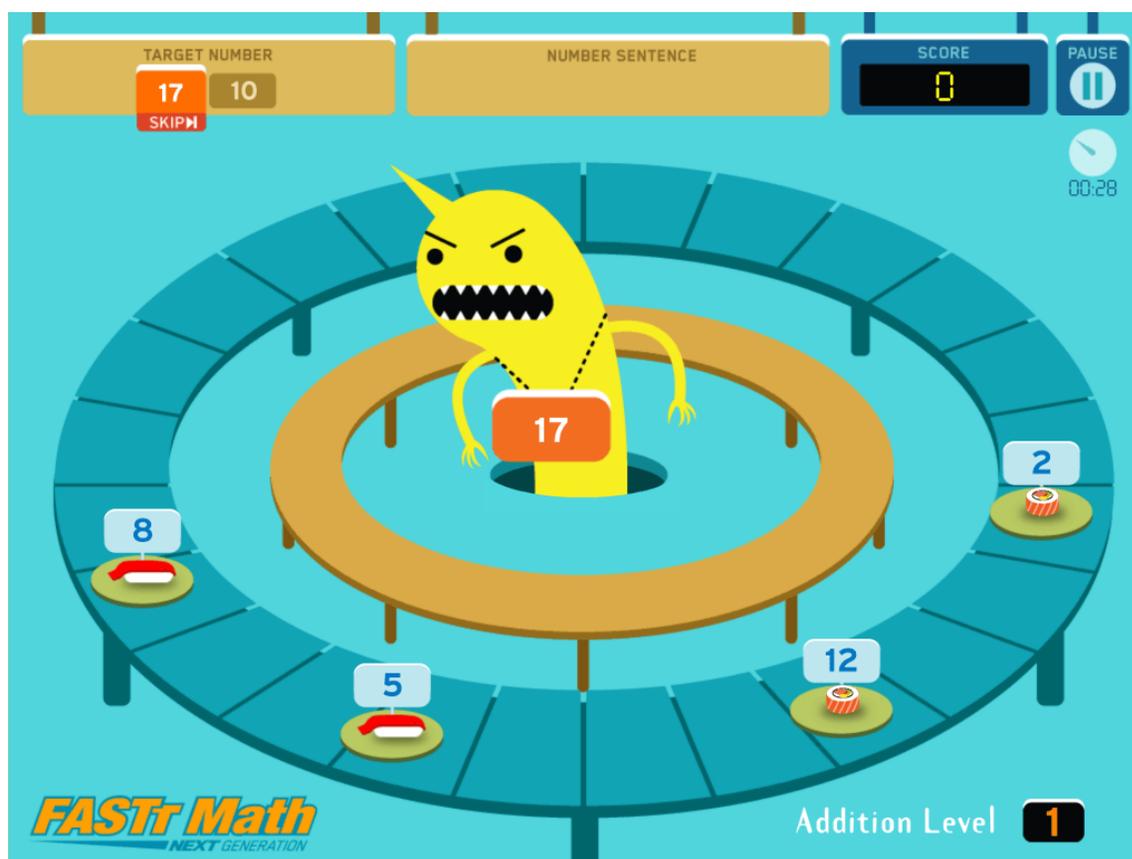
Figure 1. Math Tappers App Screen



3.5.2.2 Sushi Monster App

Sushi Monster (Figure 2) is a game that students use to practice a series of addition and multiplication tasks. Numbers appear on sushi plates, and students need to pick the correct two numbers in order to feed Sushi Monster and move to the next level. It is timed, and students can move to the next level when they successfully complete all questions. Students earn a trophy at the end of each level as a reward.

Figure 1. Sushi Monster App Screen



3.5.2.3 Thinking Blocks App

Thinking Blocks (Figure 3) help students to develop skills for solving word problems using different coloured, visual blocks. The app allows students to visualise the word problems and provides feedback and helpful hints during each step to let students know whether they are on the right track.

Figure 3. Sample Thinking Blocks Screen

Word Problem: Greta bought a supply of juice cartons for \$13, some muffins for \$19, and several brownies. She spent \$48 altogether. How much did the brownies cost?

Add numbers to your model. Use a ? to show the missing number.

total money

cost of juice cartons

cost of muffins

cost of brownies

Check

\$48

?

\$13

\$19

Feedback
Excellent work! Blocks and labels have been placed correctly. Now you can add numbers to the model.

Part Whole Model - 3 Parts

3.5.2.4 Show Me App

Show Me (Figure 4) permits teachers and students to create video presentations. They can create and insert images, add text and photos of their work and record their own voice and the screen while they are solving problems.

Figure 4. Show Me App Screen



3.5.2.5 Prodigy App

Prodigy is an adaptive game for students in grades 1-8 that focusses on mathematics skills in the curriculum. Students can build their own avatar and navigate through different villages as they complete skill-based math questions. A diagnostic test determines students' math level helps students to practice skills that they need to improve on. Questions frequency and difficult are adjusted based on student performance.

Figure 1. Sample Prodigy App Screen



3.5.3 Selection of Apps

Several steps were involved when selecting the apps for this study. First, a technology lead-teacher was consulted and suggested several apps that were used regularly at the school. Some of the apps were also recommended by the board technology lead-teachers. In addition, several education resources such as Teachers with Apps, Education World, and Smart Apps For Kids were reviewed. After consolidating the above suggestions and ratings, promising apps were selected and tested by a few students.

Observational notes were made while students were using the apps to assessed based on an evaluation rubric for iPad apps created by Walker (2011) (Appendix F). The rubric had seven evaluation criteria: curriculum connection, authenticity, feedback, differentiation, user friendliness, student motivation, and reporting. Each criterion was evaluated on a scale from level 1 to level 4. Table 3 provides an overview of each apps' evaluation based on Walker's criteria.

Table 3 – Evaluation of Apps

Domains	Math Tappers	Sushi Monster	Thinking Blocks	Show Me	Prodigy
Curriculum Connection	Level 2	Level 3	Level 3	NA	Level 4
Authenticity	Level 2	Level 2	Level 3	Level 3	Level 3
Feedback	Level 2	Level 2	Level 4	NA	Level 3
Differentiation	Level 3	Level 3	Level 3	NA	Level 4
User Friendliness	Level 4	Level 4	Level 2	Level 2	Level 4
Student Motivation	Level 4	Level 4	Level 2	Level 2	Level 4
Reporting	Level 4	Level 2	Level 3	NA	Level 4

3.5.3.1 Math Tappers' Ratings

Math Tappers requires foundational skills from students, such as adding simple two-digit numbers. The app aligns with the grade 2 curriculum where students problem-

solved using two-digit numbers involving addition and subtraction. However, it does not align with the grade 3 curriculum as students will need to use numbers up to three digits. Students can use this app in grade 3 to practice addition or subtraction skills that they learned in grade 2 (Level 2 rating). For authenticity, specific addition and subtraction skills are presented in a very simple game format (Level 2 rating). In terms of feedback, the app provides an accuracy percentage and the amount of time that was spent answering questions, but not hints or suggestions (Level 2 rating). Regarding differentiation, Math Tappers has a function where students can set different sum targets according to their own comfort level. In addition, students can choose to work with visuals (e.g. apples) or numbers (e.g. part-whole) only (Level 3 rating). With respect to user friendliness, the app is very easy to use, because it does not require separate instructions (Level 4). Students appeared to be highly motivated when using the app (Level 4 rating). Finally, for reporting, students are provided with a progress page indicating accuracy, time, and target numbers that can be emailed to teachers (Level 4 rating).

3.5.3.2 Sushi Monster Ratings

Sushi Monster allows students to practice two- and three-digit addition and subtraction skills, therefore, it matches with grade 2 and 3 math curricula (Level 4 rating). As students can practice in a contrived game format thus, Sushi apps does not provide an authentic learning environment (Level 2 rating). Students receive limited feedback as to what they did incorrectly as they complete tasks (Level 2 rating). Regarding differentiation, there are seven levels for addition/subtraction games. Students need to start at level 1 and successfully complete each level in order to move onto the next level.

However, students can go back to the level if they wish to practice more (Level 3 rating). The Sushi app was user friendly, as guided instruction was not necessary when students were using the app for the first time (Level 4 rating). Students appeared to be highly motivated while using the Sushi app (Level 4 rating). Report data was available in a simple graphic format and identified what level they achieved. This information could be shared with the teacher (Level 2 rating).

3.5.3.3 Thinking Blocks Ratings

Students can practice addition and subtraction skills using the word problem questions in Thinking Blocks. Therefore, it reinforces students' specific addition and subtraction skills up to the number 300. These skills align with the grade two and three curriculum (Level 3 rating). The app presents word problems to students, but not necessarily in an authentic real-world setting (Level 3 rating). Detailed feedback is presented when students take action, which helps them to determine if they are on the right track while solving problems (Level 4 rating). Regarding differentiation, the app allows students to alter settings by choosing different types of visual models. As students correctly answer the questions, the app provides more challenging questions (Level 3 rating). For user friendliness, students needed to have the teacher review how to use the app when first starting out (Level 2 rating). Students viewed the app as "schoolwork", because there was of a less game component compared to other apps (Level 2 rating). Finally, report detailed data was available electronically under the progress section and it could be viewed on a single summary page (Level 3).

3.5.3.4 Show Me Ratings

Show Me is a constructive learning tool where students can present their work in an electronic format. Therefore, it could not be assessed under the following criteria: curriculum connection, feedback, differentiation, and reporting. It could provide an authentic learning environment for students to explain and discuss how they solved the problems (Level 3 rating). Regarding user friendliness, students needed to have the teacher instruct them on how to use the app when first starting out (Level 2 rating). Test students did not appear to be as motivated when using this app, compared to the other apps used (Level 2 rating).

3.5.3.5 Prodigy Rating

In Prodigy, a set of question and skills are strongly connected to practice addition and subtraction skills in the grade two and three mathematics curriculum. In addition, teachers could select specific curriculum expectations (Level 4 rating). Students experience being in a microworld, which has the look and feel of being in an authentic environment. However, the world is not connected to mathematics in an authentic way (Level 3 rating). Simple feedback is provided when students do not get the right answer, a hint feature helps to improve student performance (Level 3 rating). With respect to differentiation, Prodigy alters the settings based on student performance. When students make mistakes on a specific skill, the following questions help to practice the skill (Level 4 rating). For user friendliness, students could launch and navigate through the app independently, and teacher instruction is not required (Level 4 rating). Detailed performance data is made available electronically to the student and teacher (Level 4).

3.5.4 Consent Forms

Two weeks before the study started, a parent consent form (Appendix A) was sent home. The researcher delivered the consent form to individual students. The consent form discussed the purpose, an overview of the study, and a list of expectations. Since the use of the apps was a part of the class activity, all students were given the same opportunity to use iPads, but data was only collected from students who agreed to participate in the study.

3.5.5 Knowledge Tests

The students completed pre- and post-tests for all the concepts addressed by the mathematics apps (Appendix D). The grade 2 students focused on adding and subtracting with one and two-digit numbers, whereas the grade 3 students were focused on adding and subtracting up to three-digit numbers. After five weeks of direct instruction, with five different apps, a post-test was completed. Both tests took about 40-50 minutes (one period) to complete.

3.5.6 A Unit of Study

The mathematics unit in this study was taught for five weeks. Students spent 15 to 30 minutes each day working on the iPads. The students were given guidelines on using the iPads. For example, the teacher provided rules such as iPads should be only used on a desk or a carpet, no other app should be accessed, and no visual advertisement should be accessed. The teacher taught lessons using a variety of approaches. Typically, she used math manipulatives such as beads to present the concepts of addition and subtraction. In addition, she used chart paper to present other concepts. Next, the students practised with the iPads. As an everyday routine, the teacher taught a lesson to the first group (grade 2),

while the second group (grade 3) used the iPads to practice what they learned. When the first group was done with the teacher, they would switch to the iPads while the second group received instruction. When the students had extra time during the mathematics class, they practised their skills with the iPads.

3.5.7 Surveys & Interviews

After using each app for four to five classes, the students completed a survey assessing their perceptions and experiences (Appendix C). The survey questions asked if the app helped them learn addition and subtraction skills, if it was fun and easy to use, if they would like to use the app again, and what they liked or disliked about using the app. Students completed five of these surveys – one for each mathematics app used. At the end of the study, six students were randomly selected for a 10 to a 15-minute interview with the researcher, which was recorded and transcribed (Appendix E).

3.6 Research Design and Data Analysis

A summary of data collection analysis for each research question is provided in Table 4.

Table 4 – Summary of Data Collection Analyses

Research Question	Data Type	Data Collection Analyses
1. What are grade 2 and 3 students' attitudes towards using tablets in a mathematics class?	Likert question # 4,5, 6,7,8 Open-ended question 9, 10 Interview questions	Descriptive statistics and a frequency analysis were done on the use of tablet attitude Content analyses of open-ended responses and interview questions about attitude toward tablet use

2. What is the impact of tablet use on elementary student performance?	Pre- and post-test results	Average scores on each pre- and post-test were compared using a paired t-test.
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4 Results

4.1 Attitudes Toward Using Mathematics Apps

4.1.1 Usability

Likert survey. Table 5 presents a summary of student attitudes regarding the use of apps in a mathematics class. On the 5-point Likert scale, all of the students agreed or strongly agreed that the Math Tappers app was the easiest to use, followed by the Prodigy and the Sushi Monster apps. In contrast, the Thinking Blocks and Show Me app were rated as the most difficult to use (see Table 5).

Table 5 – Usability - Ease of Use (n=20)

Items	Means (SD)	Disagree/ Strongly Disagree	Neutral	Agree/ Strongly Agree
Math Tappers	4.6 (0.5)	0%	0%	100%
Prodigy	4.5 (0.8)	0%	18%	82%
Sushi Monster	4.1 (1.0)	5%	25%	70%
Thinking Blocks	3.5 (1.2)	20%	35%	45%
Show Me	2.8 (1.4)	41%	35%	24%

Open-ended questions. Based on open-ended qualitative results, two main themes emerged: interface design of the apps and technical problems.

Regarding interface design, both positive and negative comments were offered, mostly about the Math Tappers and Think Block's apps. The students did not comment on

interface design for the Prodigy, Sushi Monster or Show Me apps. Sample comments included:

“It was easy to use because I could tap the numbers and I didn’t have to type it.” **[Math Tappers]**

“It was simple, not complicated.” **[Math Tappers]**

“It was hard to find numbers.” **[Math Tappers]**

“When I was working with a whole number, it was hard to find the numbers.” **[Math Tappers]**

“It was hard to figure out what to do.” **[Thinking Blocks]**

“I didn’t really like it because it was hard to use.” **[Thinking Blocks]**

“Sometimes when I pressed a number, it didn’t show up.” **[Thinking Blocks]**

“Sometimes the box wouldn’t be dragged from one place to another, and the steps were not clear.” **[Thinking Blocks]**

With respect to technical problems, some students (n=7) responded that the apps were difficult to use. Sample comments included:

“I didn’t know what to do.” **[Thinking Blocks]**

“It was bit boring, and sometimes when I pressed a number, it didn’t show up.” **[Thinking Blocks]**

“I didn’t really like it because it was too hard.” **[Thinking Blocks]**

“Sometimes the box wouldn’t be dragged from one place to another and steps were not clear.” **[Thinking Blocks]**

“I did not like it because it was hard for me.” **[Show Me]**

“It was hard to find the letters on the screen keyboard.” **[Show Me]**

“It was complicated and little hard to do.” **[Show Me]**

Other students (n=3) wrote how they did not like the voice recording function with the Show Me app. Sample comments were:

“Sometimes the box wouldn’t be dragged from one place to another.”

“I didn’t like recording part.”

“I didn’t like that I had to record my voice.”

The students did not report technical problems for the Math Tappers, Prodigy or Sushi Monster apps.

Interview data. Six students participated in 10-15 minute interview sessions regarding the use of mathematics apps in the class. During the interview sessions, the students raised concerns about challenges with the Show Me, Thinking Blocks, and Prodigy apps. Student 3 commented about the Show Me app: “It was challenging, because if you type the wrong thing, and if I go back, all the work is erased”. The Prodigy app did not work on iPads, and the students had to access it through Safari or Google Chrome web browser. Student 4, who commented about the Prodigy app said: “I had to use the Prodigy through Safari because the app was not working on the iPad and I used Google Chrome to use Prodigy, it was more stable”. Student 5 commented that the Thinking Block app was difficult to use: “Thinking Blocks was the hardest app to use... the questions were given to me, and I had to solve the questions. Also, I find it hard to use because there [was] a lot of information on the screen”. No comments, positive or negative, were made in the interview about the usability of the Math Tappers or Sushi Blocks apps.

4.1.2 Perceptions of Learning

4.1.2.1 Addition and Subtraction

Likert survey. Table 8 displays the survey results about whether the apps helped the students learn addition. Most of the students agreed or strongly agreed that the Prodigy app helped them learn addition followed by the Sushi Monsters and the Thinking Blocks apps. In comparison, the students indicated that the Math Tappers app was least helpful when learning addition (see Table 6).

Table 6 – Perceptions of Learning– Addition Better (n=20)

Items	Means (SD)	Disagree/ Strongly Disagree	Neutral	Agree/ Strongly Agree
Prodigy	4.5 (0.7)	0%	12%	88%
Sushi Monsters	4.2 (0.9)	0%	30%	70%
Thinking Blocks	3.8 (1.3)	10%	30%	60%
Math Tappers	3.5 (0.8)	5%	55%	40%

Table 9 summarises whether students felt the mathematics apps helped them learn to subtract (Appendix C, Item #5). The majority of the students agreed or strongly agreed that the Prodigy and, to a lesser extent, the Thinking Blocks app helped them learn to subtract better while less than one-third of the students agreed or strongly agreed that the Math Tappers and the Sushi Monster apps helped to learn subtraction (see Table 7).

Table 7 – Perception of Learning– Subtraction Better (n=20)

Items	Means (SD)	Disagree/ Strongly Disagree	Neutral	Agree/ Strongly Agree
Prodigy	4.4 (0.7)	0%	12%	88%
Thinking Blocks	3.8 (1.1)	10%	30%	60%
Sushi Monsters	2.6 (1.5)	60%	10%	30%
Math Tappers	3.0 (0.8)	30%	45%	25%

The Show Me app allows students to present and explain their thinking rather than practising specific mathematical skills. Therefore, the survey question was changed slightly from “The app helped me to learn to add or subtract better” to “The app Show Me helped me to learn to explain my work.” The results indicated that 70% of the students (n=12) agreed or strongly agreed that the Show Me app helped them learn to explain their work, 20% of the students (n=3) believed it had neither a positive nor negative effect, and 10% of the students (n=2) disagreed or strongly disagreed with the statement.

Open-ended question. In the open-ended section of the survey, many students wrote that the apps helped them learn both addition and subtraction (n=13). Four students commented about the Prodigy app. Sample comments included:

“The Prodigy helped me to add and subtract better.”
“It helped me learn addition.”
“It helped me more on adding and subtracting.”
“The Prodigy app helped them to learn mathematics skills; it helped to learn mathematics better.”

Four students noted that the Thinking Blocks app helped them learn better. Sample comments included:

“It helped me learn addition.”
“It helped me learn addition better.”
“It helped me to learn addition and subtraction.”
“It helped me to add and subtract better.”

With regards to the Math Tappers app, four students commented on how it helped them learn. Sample comments included:

“It helped to learn to add.”
“It helped to add higher numbers.”
“I got better at adding.”
“Apples helped to learn subtraction better.”

Note that students made no comments about the Sushi Monster app helping them to learn addition or subtraction.

Interview data. The students in the interviews commented that the apps helped them with addition and subtraction. With respect to addition and subtraction, three students noted the benefits of the Prodigy and Sushi Monster apps. Student 2 commented that with the Prodigy app “many questions were on adding and subtracting, and it helped me learn through playing games.” Student 6 added that in the Prodigy app “the questions

were about adding subtracting, and I liked how I won the battle when I got the questions right”. The Student 6 noted that with the Sushi Monster app, the “questions got harder whenever I got the question right, and it helped me to learn adding and subtracting better”.

Three students commented about the benefits of apps in solving word problems, specifically with the Thinking Blocks and Show Me apps. Student 1 mentioned that the “Thinking Blocks taught me how to solve word problems faster, and I got better at it after using the app”. Student 6 added that “I liked the word problems [in the Thinking Blocks app], and I liked when I had to decide if I have to do addition or subtraction for the question. It helped to solve the word problems with blocks”. Regarding the Show Me app, Student 5 said: “I like recording better than talking in front of the class, and it helped me to solve word problems”.

4.1.2.2 Helpful Features

Open-ended questions. In the open-ended section of the survey, four main themes emerged; differentiated tasks, a recording function, opportunity for redoing the work, and visuals.

Regarding differentiated tasks, the Sushi Monster and the Prodigy apps offered different levels, which allowed students to set a goal, then provided encouraging feedback to move them up to the next level and earn rewards at the end. Sample comments included:

“I like how it ... the number got higher as I moved up each level.”

[Sushi Monster]

“I liked all the cool features, such as it had different levels....”

[Sushi Monster]

“It had different levels.” **[Sushi Monster]**

“I liked how there were different monsters for different levels.”

[Sushi Monster]

"I liked how there were different monsters for each level."

[Sushi Monster]

"I like when you get to choose your world when I got the question right."

[Prodigy]

The students did not comment about differentiated tasks in the Math Tappers, Thinking Blocks or Show Me apps.

The voice recording function was available in the Show Me app. Seven students noted that they liked the recording function on the Show Me app. Samples comments included:

"I liked how I could record my voice."

"I like to record my voice."

"I liked the recording part."

"I liked how my voice got recorded; it was fun."

"I didn't have to present the work in front of the big class."

"I liked how you can record your voice."

"I like how we could record your own voice, and we were able to share it with the class."

About having the opportunity to redo work, two students commented that they liked receiving several chances to rework on questions in the Thinking Blocks app. Sample comments included:

"I like how they [the Thinking Blocks app] give three chances, and you could restart it again if you got the wrong answer."

"I liked how they give three chances to work on the question."

Regarding visual features, four students commented that they liked visuals from the Math Tappers app. Sample comments included:

"I liked apples and numbers."

"I liked both functions of showing apples and numbers."

"It had two parts, apple, and numbers and I liked the graphics."

"I liked the use of apples (visuals)."

Interview data. During the interview sessions, the students commented on collaboration, customised setting, voice recording, and graphic features of the apps. On collaboration, the students appreciated the experience of playing with their peers when they were in a virtual space game. Two students responded that they enjoyed the feature on the Prodigy app that allowed them to work with other students. Student 4 said: “I like... how you can compete with other people”. In addition, Student 5 mentioned: “I also got to do battles where we had to answer mathematics questions to win the battles”.

Regarding the customised setting, the students commented on how it helped them to create a personal connection with the apps. Student 4 mentioned that with the Thinking Blocks app: “You can pick and choose different models. It could be an easy one or challenging ones. There was also mystery ones too. I liked how I could pick and choose different models to solve a problem”. Student 6 responded: “In Math Tappers, you can choose different sum targets. I liked to use *Apple* more than the *Whole-Part* because you could choose a number to add it. You can see what is left over, and it helped to find the answer”. Three students answered that they enjoyed the feature where they could pick and choose their characters when playing mathematics games with the Prodigy app. Student 5 commented: “I like how you can choose and create your own characters and pet compared to other apps”. Student 6 remarked: “You can pick your own characters, pets...” Lastly, Student 2 mentioned: “In Prodigy, I got to create my own personal characters”.

For the voice recording function in the Show Me, several students (n=4) commented that they enjoyed it, others did not like the recording feature of the app. Student 5 mentioned: “I liked the recording function much better than presenting my work in front of

the class”. In contrast, Student 3 responded: “I didn’t like the recording part because it was too noisy in the classroom. It picked up the background noise”. Student 4 remarked: “If I made mistakes when recording, I had to go back and record it again. I almost had to have a script ready before I record the voice”. In addition, Student 6 said: “I didn’t like the recording because you had to record your own voice...”

In regards to graphics in the apps, several students (n=4) answered that the visuals benefited their learning. Student 1 said about the Sushi Monster app: “I liked to watch how Sushi Monster was eating the plate when I got the right question. It was more engaging”. Student 5 commented about the Math Tappers app: “I liked how there was a choice of using graphics and numbers, I used apples to solve questions”. Student 6 remarked: “... there were more graphics in Sushi Monster, and it was more engaging”. Student 6 also commented on the Math Tappers: “I liked to use *Apple* more than the *Whole-Part* (because you could choose a number and add it—you can see what is left over, and it was easier to find the answer)”.

4.1.2.3 Feedback

Open-ended questions. In regards to feedback, the students responded that they enjoyed immediate and positive feedback from the apps and that negative feedback discouraged them. Some students (n=4) indicated that they liked receiving immediate feedback from the Thinking Blocks app. Sample comments indicated:

“I like feedback and hint that was provided to me at the bottom of the screen.”

“It gave me good feedback when I got it wrong, and it helped me to solve problems.”

“I liked it gave me feedback and some information on how to solve the problem.”

“It gave me feedback and hint, so I liked it.”

Most students (n=18) responded to the positive feedback that they received from the apps. Eleven out of 18 students responded that they liked receiving positive feedback in the form of rewards as they solved questions on the Prodigy app. Sample comments included:

“I liked when my pets evolved.”

“I liked the battle part and pets, you can earn money.”

“There is a strong weapon, and you can catch the pets.”

“You can evolve and get new armours like hat or shoes.”

“You could win jackets, shoes, money.”

“I liked spills and how I got to pick outfits.”

“I liked how you can buy stuff with your money.”

“I liked how we got to battle and got money.”

“I liked collecting pets to help challenge people.”

“I liked all the fun pets...”

Four students commented about the positive feedback from the Sushi Monster app.

Sample comments included:

“I liked when I completed each game because I earned a star.”

“It did not allow to go onto the next level when you only earned one star; you have to earn at least 2-3 stars to move on to the next level, and I liked getting the stars.”

“We got trophies at the end of each level!”

“I like how it gave me a trophy.”

Two students mentioned the Thinking Blocks app, and one said:

“I liked getting five stars.”

“I liked that they had many stars and a certificate.”

One student commented about the Math Tappers app: “When I got the right answers, I felt funny when the number disappeared on me”. The student did not report any comments about receiving positive feedback about the Show Me app.

A number of students (n=9) wrote that they did not like the negative feedback that they received from the apps. For the Sushi Monster app, sample comments were

“When you get the question wrong, the monster’s eye turned into red, and I didn’t like it.”

“I didn’t like the monster when he gets mad because you got the question wrong. It was intimidating.”

“I didn’t like when I got my answer wrong.”

“I didn’t like how it skips the number when you use a different set of numbers. It would say I got it wrong, or there are not enough numbers to make a targeted number.”

“I didn’t like when I got the question wrong; the different question came up. It didn’t allow me to correct the answer.”

Regarding the Prodigy app, two students responded how they did not like the feedback they were getting when they got the question wrong. Sample comments included:

“If you get a question wrong, your opponent gets to shoot you and kill you.”

“I didn’t like when I got the question wrong.”

Note that the students did not make any comments about negative feedback on the Thinking Blocks, Show Me, and Math Tapper's apps.

Interview data. Several students commented about feedback feature of the Prodigy and Thinking Blocks apps. In the Prodigy app, the students talked about both positive and negative feedback. Student 3 commented, “In Prodigy, you can earn pets, and choose your own character, and you can get harder questions when you go to a higher level”. Student 4 remarked about the Prodigy app: “You also get money and buy a pet with money that you earned”. In contrast, Student 6 mentioned, “If you get the question wrong, you lose the battle. There were more consequences behind this game compared to the Sushi Monster. If you lose the battle, you can also lose the power”.

In the Thinking Blocks app, some students mentioned how feedback was not helpful. Student 6 commented, “I don’t read feedback, there were (*sic*) too much going on the screen”. Student 5 remarked, “Information on the screen was too much, I prefer simpler version of the app”. Finally, student 4 noted, “The feedback at each stage weren’t helpful”.

4.1.2.4 Challenging Tasks

Open-ended questions. Two main themes emerged from the open-ended questions: challenge and ease of use. Regarding challenge, many students (n=8) indicated that they enjoyed working with challenging questions. For example, three students commented on how the challenging tasks for the Thinking Blocks, Math Tappers, and Prodigy apps helped them to learn mathematics skills. Sample comments were:

“The question got harder when I got the right question, and I liked how it challenged me.” **[Thinking Blocks]**

“I liked how the level went up to 7, and it got harder for me. It helped me learn.” **[Thinking Blocks]**

“It was hard; even the lowest level was hard for me, and I like challenges.” **[Thinking Blocks]**

“The question got harder as I got the right answers, and it helped to learn to add and to subtract better.” **[Math Tappers]**

“There were some challenging questions, and it helped me learn.” **[Math Tappers]**

“Once we got the question right, it gave me another challenging **question**, and I liked how it challenged me”. **[Prodigy]**

In contrast, some students (n=5) remarked that the apps were too easy for their learning. Sample comments indicated:

“Math Tappers was too easy for me, not challenging enough.” **[Math Tappers]**

“It was too easy and competitive.” **[Math Tappers]**

“It was too easy.” **[Math Tappers]**

“It was too easy.” **[Thinking Blocks]**

“I didn’t like it because it was too easy.” **[Thinking Blocks]**

The students did not comment on challenging tasks for the Show Me and Sushi Monster apps.

Interview data. As it indicated in the open-ended responses, the interview data also reflected the same main themes; challenging tasks and ease of use. Two out of six interviewed students responded that they enjoyed being challenged and had better learning outcomes. Student 6 commented, “In Sushi Monster, questions got harder, and it helped me learn to add and to subtract better”. Student 3 responded, “Thinking Blocks challenged you, because every time I get the question right, it gave me more challenging questions”.

One student mentioned how the Prodigy app was not challenging enough for their learning. Student 5 commented,

“It would have been better if it was harder. The level wasn’t challenging enough; I kept winning the [*sic*] battles, and I wanted to try the harder question, but it didn’t give me harder questions. I was winning the game, but the level wasn’t challenging enough”.

4.1.3 Engagement

Likert survey. Table 6 summarises student ratings on how fun each app was to use (Appendix C, Item #7). All students agreed or strongly agreed that the Prodigy app was fun to use. In addition, many of the students agreed or strongly agreed that the Math Tappers and Sushi Monster apps were fun to use, whereas 60 to 65% agreed or strongly agreed that the Thinking Blocks and Show Me app were fun to use (see Table 8).

Table 8 – Student Attitudes Toward Apps (Engagement) - Fun to Use (n=20)

Items	Means (SD)	Disagree/ Strongly Disagree	Neutral	Agree/ Strongly Agree
Prodigy	4.9 (0.3)	0%	0%	100%
Math Tappers	4.6 (0.7)	0%	10%	90%
Sushi Monster	4.5 (0.8)	0%	15%	85%
Thinking Blocks	3.9 (0.8)	25%	10%	65%
Show Me	3.4 (1.4)	30%	12%	58%

Open-ended questions. In the open-ended questions, students commented on three apps on engagement: Sushi Monster, Math Tappers, and Thinking Blocks. In the Sushi Monster app, six students commented that it was fun to use. Sample comments were:

“It was fun, and I liked all the cool features, such as expression of the Sushi Monster.”

“I liked how Sushi Monster gobbled up the sushi when I got the question correct.”

“Sushi Monster character gobbled funny.”

“It was a fun game.”

“It was a fun game.”

“It was fun, and I liked all the cool features.”

In regards to the Math Tappers app, three students responded that they had fun using the app students noted how the Thinking Blocks app helped them learn problem-solving question. Sample comments mentioned:

“It was fun to practice, and I got better at it.”

“I liked that it was fun because it was very well designed and interesting to use.”

“It was fun because you got to do more challenges and you can buy stuff with your rewards. It just felt I like was in the game.”

Two students noted how the Thinking Blocks app helped them learn problem-solving questions and was fun to use. Sample comments included:

“It was fun doing adding and subtracting with the Thinking Blocks app.”

“I liked it because it helped me to learn better and it was fun.”

Note that students made no comments about the Prodigy and Show Me apps being engaging or fun to use.

Interview data. During the interview sessions, the students had to list their favourite to least favourite apps, and discuss what they liked and disliked about each app. Five students responded that the apps were fun to use. Two students commented about the Sushi Monster app. Student 1 mentioned, “I think Sushi Monster was the most fun one because you get to see Sushi Monster’s expression”. Student 4 remarked, “It was fun to watch them eating plates”. In regards to the Math Tappers app, Student 6 remarked, “Math Tapper was fun and gave me actual numbers to add to solve the question”. Student 5 also noted about the Math Tappers app: “I liked it because it was fun and if you don’t like one part, you have a choice to do other things, like you can work with *Apples* or numbers to solve problems”. In addition, Student 5 commented about the Prodigy app, “I liked how you can choose your own character, and it was fun”. Student 2 noted that Thinking Blocks app, “was fun to use”.

4.1.4 Future Use of App

Likert survey. Table 9 summarises whether the students would like to use the apps again (Appendix C, Item #8). All the students responded that they would use the Prodigy app again. Close to three-quarters of the students agreed or strongly agreed that they would like to use the Math Tappers and Sushi Monsters apps again. In contrast, approximately half the students agreed or strongly agreed they wanted to use the Thinking Blocks or Show Me apps again (see Table 9).

Table 9 – Student Attitudes Toward Apps – Future use of app (n=20)

Items	Means (SD)	Disagree/ Strongly Disagree	Neutral	Agree/ Strongly Agree
Prodigy	4.9 (0.3)	0%	0%	100%
Math Tappers	4.0 (1.3)	10%	15%	75%
Sushi Monsters	3.9 (1.1)	10%	20%	70%
Thinking Blocks	3.5 (1.5)	25%	20%	55%
Show Me	3.3 (1.6)	30%	24%	46%

Interview data. Six students responded to 10-15 minute interview session regarding the use of mathematics apps in the class. One of the students commented about reusing the apps: “I would like to use the apps for mathematics class again”.

4.2 Summary of Apps Used

Table 10 summarises the results of the survey scores by ranking each mathematics app on the key categories assessed. The three game-based apps (Prodigy, Math Tappers, and Sushi Monster) had the highest rankings. The Prodigy app ranked highest or second highest in all five categories. The Math Tappers app was perceived as being easy to use and engaging. However, it ranked the lowest regarding the perception of learning. The Sushi Monster app received a moderate ranking in all five categories and was perceived as a better learning tool than the Math Tappers apps.

The two non-game-based apps, the Thinking Blocks and the Show Me apps, had the lowest rankings. The Thinking Blocks app was reported as relatively difficult to use and not engaging. In addition, the perception of learning was similar to the Sushi Monster app. The Show Me app had the lowest ranking of the all five apps. Students had difficulty using the app and perceived that it was not engaging. The Show Me app was considered as a

production tool rather than a learning tool. Thus, the perception of learning was not asked as part of a survey.

Table 10. Rank Ordering of Survey Score or Mathematics Apps (n=20)

Items	Usability	Perception of Learning (Addition)	Perception of Learning (Subtraction)	Attitude (Engagement)	Attitude (Future use of App)	Total Score	Rank
Prodigy	4	4	4	5	5	22	1
Math Tappers	5	1	1	4	4	15	2
Sushi Monster	3	3	2	3	3	14	3
Thinking Blocks	2	2	3	2	2	11	4
Show Me	1	NA	NA	1	1	3	NA

Table 11 summarises the comments from the survey results for each app. The rankings for Table 10 and 11 are identical. The three highest apps were game-based apps. Overall, many students commented about helpful features in all apps. In fact, the Prodigy app had the most comments about helpful features and the perception of learning. The Sushi Monster app had the most comments for engagement. The Math Tappers app received both positive and negative usability comments, and few students commented about engagement.

The Thinking Blocks and the Show Me apps, which are non-game-based apps, were ranked lowest. The Thinking Blocks app has a number of helpful features, yet it was hard for students to use. In addition, the Show Me app has some helpful features, but its engagement level was quite low and was hard to use. Moreover, students did not comment about engagement.

Table 11. Summary Scores for Mathematics Apps: Number of Comments (n=20)

Items	Usability (Pos.)	Usability (Neg.)	Perception of Learning (Positive)	Helpful Features	Challenge	Attitude (Engage)	Total Score	Rank
Prodigy	0	0	4	11	1	0	16	1
Sushi Monster	0	0	0	9	0	6	15	2
Math Tappers	2	-2	4	4	2	3	13	3
Thinking Blocks	0	-8	4	8	3	2	9	4
Show Me	0	-3	0	7	0	0	4	5

4.3 Impact of Mathematics Apps on Student Performance

Pre and post-tests were conducted to assess students' performance levels before and after using mathematics apps. The paired t-test revealed that the mean learning performance scores were significantly higher after the use of mathematics apps ($M=75.8$, $SD=21.5$) than before ($M=59.7$, $SD=20.1$) ($t(19)=3.1$, $p<0.005$, $d= 0.80$). According to Cohen (1988, 1992), the difference between means, a 16% increase, was considered large based on the Cohen's d value of 0.80.

5 Discussion

The purpose of this study was to investigate the mathematics apps use in a primary class. Two main questions were addressed:

1. What are attitudes of grade 2/3 students toward using mathematics apps in a class?
2. What is the impact of the use of mathematics apps on elementary students' performance?

5.1 Attitudes Toward Mathematics Apps

5.1.1 Usability

Previous research suggested that tablets are relatively easy to use (Allouch et al., 2014; Bush & Cameron, 2011; Craft et al., 2013; Kyanka-Maggart, 2013; Tsuei, 2012). However, in this study, ease of use was a more complicated concept and dependent on the interactions that students had with a specific type of app. According to the survey results, game-based apps were perceived as easier to use because students were able to interact with the apps with only limited guidance. Non-game-based apps, such as the Thinking Blocks app and the Show Me app, required more cognitive effort. Thus students found them more challenging. The research finding for usability suggests that the software design and interface of the app impacts student learning more than the ease of use of the device. Therefore, future research could focus on the way that apps are designed to enhance student learning, which ultimately affects students' attitudes.

5.1.2 Perception of Learning

5.1.2.1 Addition and Subtraction

Previous research indicated that students gained mathematics knowledge while they were working on tablets (Alon et al., 2015c; Finn et al., 2014; Harris, 2015; Kyanka-Maggart, 2013; Riconscente, 2013). The results of the current study confirmed that students perceived gain in mathematics knowledge using tablets, but these gains might be dependent on the type of mathematics application used.

Five apps (Prodigy, Sushi Monster, Math Tappers, Thinking Blocks, and Show Me) were reviewed in this study. Students rated Prodigy as their most supportive app for learning. It is a game-based app, which is designed to accommodate students' individual strengths and weaknesses based on their answers. If students get a right answer, the program provides them with a more challenging question. If they get a wrong answer, the program provides an easier question to build their skills. This adaptive, personalised feature may have contributed to students' perception of learning.

Students believed that more learning occurred when using challenging apps, such as Thinking Blocks. Although they believed the app was hard to use, the app's additional features, such as immediate feedback and use of virtual models, helped them to visualise the learning process. Immediate feedback was provided in a sentence format. Finally, students could also use colourful blocks to visualise mathematics problems by dragging the blocks into a pre-designed bar. Immediate feedback and visualisation may have helped students to learn.

The Sushi Monster app is a game-based app, where a monster is eating sushi off from a plate when students get a right answer. According to the interview data, the visual and audio effects of the game helped students stay focused while answering questions. Also, when students got the right answer within a certain time frame, they were rewarded with a trophy. These features might have provided better opportunities for students to gain addition and subtraction skills.

Although many students perceived that the Math Tappers app was easy to use, the survey results indicated that it did not support students' learning compared to other apps. As the nature of the Math Tappers app is to practice simple addition and subtraction skills, it may not have challenged all learners equally. Students who were comfortable with two to three digit addition and subtraction skills expressed that they did not learn much from the app. Without the personalised adjustment of questions based on student answers, used in Prodigy, for example, questions may not have correctly matched each student's ability and skill level.

The Show Me app was not designed to practice mathematics skills. It is a constructive learning tool that allows students to express their thinking process while solving mathematics questions. This app was difficult to use for this age group, and the cognitive effort required to use the tool may have undermined the learning of mathematics concepts. It is important to recognise how constructive tools could affect learning negatively.

No previous research has examined the relationship between the app's usability and students' perception of learning, as this is a new area of study. This study suggests that

specific functionality of apps may influence how much learning can be done. However, more detailed qualitative research is needed to identify specific features of apps that may help or hinder learning. Future research may specifically focus on how features and functionalities of an app may contribute to or undermine students' learning is needed. In addition, it is important to consider the students' prior knowledge- some students might need more challenging apps, whereas other students may need to practice basic skills.

5.1.2.2 Helpful Features

Based on the interview data, a number of students reported that they liked the feature of personalised characters when using game apps. For example, in the Prodigy app, the virtual avatar represented their character in the online world. The effectiveness of personalization in this study is consistent with the research by Finn et al. (2014) who indicated that the adoption of character development is an important factor in improving the engagement of students because they experience an emotional bond between themselves and the customised characters while playing games. If the players do not customise a character, their participation level decreases (Finn et al., 2014). Other apps like Math Tappers, Sushi Monster and Thinking Blocks did not have personalization features, and the lack of personalization may have undermined the effectiveness of these apps. This finding is based on a small number of interviews, and further research is needed to identify whether the personalization is a critical aspect of learning.

In addition, the results of this study suggested that differentiated instruction was another helpful feature. For example, the Prodigy app assessed students' mathematics level as they were playing, and adjusted the questions accordingly. The Math Tappers,

Sushi Monster and Thinking Blocks apps allowed students to choose different levels that challenged their learning, yet it was rated as not as effective as the Prodigy app. These apps may not have been as successful as the Prodigy app because the differentiation was not based on actual student performance. This finding is consistent with the research by Beck-Hill and Rosen (2012), Boogart et al. (2014), Ciampa (2014), and Clark and Luckin (2013) who mentioned that individualised settings enhance student learning and help improve students' engagement. Further investigations of the effectiveness of the differentiating instruction are needed to determine whether the real-time differentiation is critical to student success.

5.1.2.3 Feedback

The students in this study noted that immediate feedback was helpful to their learning. All apps provided feedback, which was highly rated by students. This result is consistent with research on the effectiveness of immediate feedback (Brummel et al.,2013; Clark & Luckin, 2013; Galligan et al. 2010; Keengwe 2013; Kocak 2015; Kyanka-Maggart 2013; Riconscente 2013; Tabor 2014). These studies indicated that instant feedback is motivating and engaging for students, leading to increased performance in mathematics.

However, the details and the quality of feedback, whether it was written or simple visual feedback, may have influenced the students' perceptions and learning. It was clear that specific types of feedback were preferred over other types of feedback. For example, in the Thinking Blocks app, written feedback was provided at the bottom of the screen when a student completed each step to answer a question. When the student was correct, the app provided a positive comment, which allowed them to move on to the next

step. When the student was incorrect, the Thinking Blocks app provided an explanation to edit the work. While this form of feedback might seem reasonable for older students, simple rather than detailed feedback might have been more effective for grade 2 and 3 students who were just learning how to read. With the simple visual feedback in the Math Tappers, Prodigy, and Sushi Monster apps, students could immediately determine whether they obtained right or wrong answers without having to read detailed comments. Students reported that this type of visual, immediate feedback was a very helpful feature.

Some of the apps generated both positive and negative feedback. Based on the survey results, it was clear that the students preferred receiving positive responses (e.g., earning rewards, trophies) from the app like Sushi Monster, rather than negative responses (e.g., negative facial expressions, losing power to fight against another opponent) like the Sushi Monster and Prodigy apps. The students did not like receiving negative feedback - they reported that it made them feel uncomfortable. The students mentioned that positive feedback provided in the Thinking Blocks, Sushi Monster, and Prodigy apps, such as rewards, was motivating and engaging. Previous researchers suggest that incentives and rewards are important for students to remain highly engaged (Bhanot, 2009; Isabwe, 2012; Swicegood, 2015). It is worth noting, however, that the positive or negative nature of feedback might not have a significant impact on learning. For example, in the Prodigy app, students' avatars lost power when not getting the right answer (negative feedback), yet it was perceived as the most effective learning tool in the study. Future research needs to be conducted on whether the quality of negative or positive feedback has an impact on student learning.

5.1.2.4 Challenging Tasks

According to the survey results, students responded that the challenging questions helped their learning. Grade 2 and 3 students enjoyed learning through challenging tasks instead of merely focusing on the fun part of the game. For example, students indicated that the Thinking Blocks app helped them to learn while working on challenging questions. The students may not have enjoyed the challenging tasks, but they believed that they were gaining mathematics knowledge while working on the task. In addition, students were bored with easy questions, as they indicated in the Math Tappers survey. This result is consistent with Swicegood's (2015) finding, which noted that difficult tasks were both challenging and fun for the students in a grade 2 mathematics class. The further in-depth investigation into students' attitude and learning with challenging tasks is needed to confirm this finding, as the study's sample size was small. In addition, it would be worth exploring optimal levels of challenge for students. It is conceivable that too much of a challenge might inhibit learning and discourage students.

5.1.3 Engagement

5.1.3.1 Fun to Use

A number of studies found that elementary students have positive attitudes towards tablets (e.g. Allouch, 2014; Bloemsma, 2013; Heinrich, 2012; Kaciupski, 2013). However, these studies did not review the impact of specific mathematics apps. It is argued that attitudes toward apps rather than general tablet technology are more accurate on assessing engagement. Assessing attitudes toward tablets is too general to provide helpful

information about the learning experience for students. Thus, in this study, younger students were asked whether apps were “fun to use”.

The results indicated that Prodigy, a game-based app, was rated as the most fun app to use, followed by the Math Tappers and Sushi Monster. Prodigy requires many different levels of interaction from students compared to the other game based apps. Prodigy has its micro-world where students navigate from one place to another as they solve problems. Students also receive interesting storylines to help stimulate engagement. This level of interaction appears to engage elementary-level students.

Math Tappers and Sushi Monster are similar game based apps, in that they allow students to practice simple addition and subtraction skills with some feedback. Although both Math Tappers and Sushi Monster apps are considered game based, they are simplified versions compared to Prodigy. They are based more on the behaviourist principles of reward and punishment. While motivating to a certain extent, the absence of storyline or integration into a micro-world may explain why they are rated as less “fun” than Prodigy.

In contrast, Thinking Blocks required students to solve word problems using different visuals, and provided feedback throughout the process. The app requires students to solve mathematics problems, and it does not have a game component to it. Interestingly, while students believed it was not as fun to use as the game-based apps, they also believed that it helped them to learn addition and subtraction skills better. Although student learning is the ultimate goal, it is critical to consider a delicate balance between engagement and the helpfulness of an app for learning. Fun to use is not always the best indicator of whether learning will occur.

Show Me was a presentation tool where students demonstrated their knowledge by recording their thinking process as they were solving mathematics problems. It was not perceived as fun to use, possibly because the majority of time was spent learning how to use the app. In addition, demonstrating knowledge could be a complex task for this age group. If it takes a long time for students to learn how to use an app and if an app is not a good cognitive match for the age level, students may be less engaged, and learn less.

Overall, an app that has a micro-world component appears to provide maximum engagement for students. Math Tappers and Sushi Monster are skill practising apps, and although the apps provide rewards, they do not necessarily translate to engagement. Thinking Blocks was not fun to use, but students felt it helped their learning. Show Me was the least favourite app— the amount of time that was spent to learn how to use the app was extensive and, therefore, students lost interest.

5.1.4 Future Use of Apps

Overall, students rated Prodigy as the app they most wanted to use again. Students also believed that they learned the most from the app. The Prodigy app adapted to students' individual abilities. Therefore, regardless of students' academic levels, it was perceived as beneficial to students' learning.

Math Tappers and Sushi Monster apps were also rated as apps that students would like to use in the future, probably because they were easy and fun to use. However, these two apps addressed relatively simple addition questions and may not have been engaging for students who already mastered these basic skills.

In contrast, some students disagreed that the Show Me and Thinking Blocks apps were either easy or fun to use and stated that they would not like to use them again. Whether or not students would use the apps again could reflect the cognitive levels of the students in mathematics. It is important to match apps with students' abilities. A certain type of apps may be better for certain levels of students. For instance, the Thinking Blocks app allows students to learn more complex sets of mathematics knowledge.

Swicegood (2015) discusses the idea of how students enjoy more challenging questions than less challenging questions. In this study, challenge depended on students' ability level. While students enjoyed challenging questions, different types of students enjoyed different levels of challenges. Future studies could be conducted on the relationship between specific types of apps and students' mathematics ability. Also, it is important to predetermine students' mathematics skill levels to decide how certain apps can be most beneficial for students.

5.2 Impact of Math Apps Uses on Students' Performance

Based on the paired t-test result, it was clear that the students' performance significantly improved after they used the mathematics apps. This finding is consistent with previous research studies that showed that students' academic performance improves after the implementation of tablets (Alon et al., 2015a, 2015b; Asam et al., 2015; Bebell et al., 2012; Boogart et al., 2014; Brummel et al., 2013; Choi et al., 2012; Donehower et al., 2013; Garwood, 2013; Harris, 2015; Herinrich, 2012; Herro, 2012; Keengwe, 2013; Pitchford, 2014; Riconscente, 2013; Swicegood, 2015; Tabor, 2014; Trujillo et al., 2013). However, students' prior knowledge, the quality of the teacher's instruction, the support

that students received from their parents at home, and other mathematics manipulatives such as the use of mini-blocks and worksheets, most likely influenced the positive test results. Therefore, it is unreasonable to suggest that the mathematics apps were the only factor that enhanced students' performance. Students were engaged in the learning process while experiencing mathematics apps, which may have helped to improve their mathematics skills.

A teacher, support from home, and prior knowledge are important factors that will impact students, yet it is important to match the correct app to student skill level, unless the app automatically adjusts to student ability, like Prodigy. It is likely best to view math apps, when carefully selected, as additional tools for helping students learn. The important step is to match the app to the cognitive ability of each student. Future studies could focus on the impact of a specific app on student learning.

5.3 Limitations and Future Research

To ensure the quality of this study, triangulation of data was employed—involving detailed qualitative and interview data to interpret quantitative results. Furthermore, the apps were carefully pre-selected based on a set of criteria (Appendix F). However, there were several limitations in this study, including a small sample size, which made it difficult to determine the reliability and validity of the study; the background of the population; the method of collecting qualitative and interview data; the accurate measurement of student engagement level; and lack of teacher observation and perspective. Each of these will be discussed in turn.

In this study, twenty students from a grade 2/3 class were selected as a sample population. Based on the small sample size, the results cannot be generalised to represent all primary students. Due to the small sample size, it was also hard to determine the reliability and validity of the results. Additional research that involves more students in different school environments is needed to establish the reliability, validity and applicability of the results.

Another bias, not accounted for in the study, could be family background. For example, students who live primarily in wealthy neighbourhoods may receive more financial or educational support and may own a tablet at home. Therefore, a more heterogeneous sample should be examined in the future.

Furthermore, the method of collecting qualitative and interview data could be biased due to the students' age group and their limited ability to convey their opinions through written and verbal formats. When receiving the responses to the open-ended section of the survey, a number of the students did not have the writing skills to convey their ideas, which limited the quality of their responses. In addition, when conducting interviews with selected students, the researcher had to ask many prompting questions, as some students did not have strong enough verbal skills to convey their ideas. This prompting may have skewed the interview responses. Therefore, a more carefully structured interview session or observational data might be useful in future studies.

In addition, the 'fun to use' section of the survey did not distinguish between an app being enjoyable to use versus cognitively engaging. Therefore, to determine the level of

engagement, future studies should clearly separate these two affective and cognitive components.

Moreover, this study focuses on low-level mathematics practice skills, such as simple addition and subtraction computational skills. Thus, it would be useful to focus on the role of the conceptual development of students when using different types of apps in a future study.

Finally, this study did not assess the homeroom teacher's perceptions of math app use. Thus, it might be helpful to conduct an in-depth interview with the teacher to obtain more information about the teacher's perspective about how students were learning using specific types of mathematics apps.

5.4 Educational Implications

There are five educational implications based on the results of the study. First, the results indicated that applications determine engagement in learning, not tablets. In this study, five different apps were used. Sushi Monsters and Math Tappers could benefit students who needed to practice simple computations. Thinking Blocks might be appropriate for students with more advanced skills. Prodigy seems to be suitable for all students as it adjusts to students' learning levels, and it is highly engaging. The Show Me app was too difficult for primary students because it took a long time for them to learn the app. Therefore, matching a difficulty level of an app with the students' abilities is critical. The use of mathematics apps may support student learning, but it is important to consider several features when selecting mathematics apps.

Secondly, the results indicated that students learn better with adaptive, personalised features. Customization of apps helps students to make a personal connection with the apps, which will help students focus while using apps. In addition, providing specific question levels that match students' abilities will maximise student learning. The repetitive practice of mathematics questions will help students improve areas where they are weakest.

In addition, the study noted the importance of providing immediate feedback. It motivates and engages students, yet different types of feedback are needed to suit students' levels. Positive, simple and visual feedback are ideal for primary students. Therefore, the presentation of feedback to students would be important to review before selecting apps.

Next, the study showed that game-based apps are user-friendly. However, not all game-based apps benefit all students. Simple drill apps could be helpful to some students who need simple practice, whereas the micro-world type of game apps, such as Prodigy, are learning tools that will support different levels of students. Fun is not always the best indicator of whether learning will occur. Therefore, it is critical to consider a balance between engagement and helpfulness when selecting apps for learning.

Moreover, in this study, the Show Me app took extensive time for students to learn, resulting in a loss of interest. Therefore, it should be easy and intuitive for students to learn how to use the app so they can spend more time solving problems within the app. In addition, teachers will need to consider the time it will take students to learn the apps. Students may require more detailed lessons about how to use apps. Unless it is a simple drill app, students would need extra practice and explicit instruction before they felt

comfortable using the apps. Thus, teachers would need to understand the different type of learners and effectively plan when using current mathematics apps. Professional development is necessary for teachers to enhance the adaptation to new apps to meet these requirements.

5.5 Summary

This study has five key findings. First, it is important to focus on the quality of a mathematics app rather than tablet use itself. Many previous studies focused on the use of tablet technology in mathematics, but not specific student behaviour while learning with applications. Second, many students had positive attitudes toward the use of mathematics apps in the class. The most popular app amongst the students was a micro-world type app that allowed students to establish a personal bond between a game character and themselves, and which provided different types of questions to match the students' ability levels. Third, the students noted that apps that are fun to use might not necessarily be helpful. For example, students rated Math Tappers and Sushi Monster as fun to use because they were game-based apps, but students did not believe that they were helpful with learning mathematical skills. Fourth, elementary students appear to benefit from immediate and positive feedback in the form of rewards. However, they did not appreciate negative feedback when they were playing app-based games. Finally, the students liked to be challenged by their learning and enjoyed solving difficult problems because they felt engaged by those tasks. Therefore, it is important to understand the students' prior experience and their learning goals when selecting apps. Some students thought that a simple app, such as the Math Tappers app, was great because their knowledge was basic

and required simple drill practice. Other students preferred more challenging tasks, such as those provided by Think Blocks, for example, because they had already mastered the necessary skills and needed to move on to more difficult skills.

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Appendix A – Consent Forms

Dear Parents / Guardians,

My name is Jasmin (Jae Yeon) Kwak and your child is invited to participate in a research study designed to investigate the use of tablets in the classroom. I am currently working on a research project called, 'Exploring the use of tablets in elementary school mathematics classrooms', looking at the impact of tablet use in elementary school mathematics classrooms, as part of a Master's of Arts program at the University of Ontario Institute of Technology. Dr. Robin Kay, who is a professor in the Education Department, is supervising this study.

I would be most grateful if you would allow your child to take part in this study. Due to increased use of tablets, such as the iPad, I would like to investigate how much impact there is on students' learning, especially in the mathematics class. As part of the grade 2/3 mathematics curriculum, a unit of Number Sense will be taught using iPads for one semester. Ms. L will teach the class using iPads in the upcoming Number Sense Unit.

The following are the steps for the students' learning:

Step 1: A pre-test will be conducted as part of a screening process before starting the Number Sense Unit.

Step 2: Lessons will be given, and a few apps will be introduced.

Step 3: Time will be given for exploration and practice with the apps.

Step 4: A post-test will be conducted as part of the Number Sense Unit.

Step 5: Students and parents who agree to participate in the study will complete the survey about the apps used during the Number Sense Unit.

Step 6: Students and parents who agreed to participate in the interview will be asked a few questions about their experience using the apps as part of the Number Sense Unit.

Students who participate in the study will be asked to complete a short questionnaire, which takes around 10-15 minutes at the end of each unit. I will randomly select a number of students to conduct a more detailed interview, lasting around 10 minutes. Students will also write a pre-test before lessons as well as a post-test. All students' answers are highly confidential and anonymous. If you wish to withdraw your child from this study, the survey and interview questions will not be asked. However, the pre and the post-test will still be given as part of the math activities.

I do require individual permission from parents/guardians to allow students to participate. If you would like your child to take part, please return a signed copy of the slip below by November 10, 2015. There are two sections for parents and/or guardians to check off. One section gives me permission to use the pre and post-test results in the study, and the other section gives permission for your child to participate in an interview session. In addition, you will need to check the boxes under "Parents/ Guardians", and your child will need to check the boxes under "Student." Both you and your child will need to sign the form if you wish to participate. There is no obligation for your child to participate in this study, and it will not impact your child's grades. Should you decide after the study is completed that you no longer want your child's data to be included, simply contact me by November 30, 2015 and I will withdraw your child from the study.

The University of Ontario Institute of Technology Research Ethics Board approved this research project on July 2015. If you have any further questions, please do not hesitate to send me an email at jaeyeon.kwak@yrdsb.ca. Any questions regarding your rights as a participant, complaints or adverse events may be addressed to the Research Ethics Board through the Compliance Office (905 721 8668 ext. 3693). By consenting, you do not waive any rights to legal recourse in the event of research-related harm.

Thank you for your co-operation.

Yours sincerely,

J. Kwak

UOIT REB file number: 14-130

Appendix B – Thank you Letter

Dear Parents / Guardians,

I would like to thank each of you for allowing your children to participate in a research study on the use of tablets in the mathematics class. It was both interesting and useful to observe and review the students' responses about the use of tablets.

In this study, the students were interviewed after their use of tablets for a Number Sense unit. Also, pre- and post-tests, as well as a survey, were conducted. Based on prior research, there were mixed results about tablet use and its impact on student performance. However, based on the results of this study, it was clear that _____.

I hope this information gives you a better understanding of the study. If you have any questions or concerns, please do not hesitate to send me an email at jaeyeon.kwak@yrdsb.ca. Thank you for your co-operation.

Yours Sincerely,

J.Kwak

Graduate Student

Department of Education, University of Ontario Institute of Technology

Appendix C – Surveys: iPad use in Mathematics class

Math Tappers Survey

1. Are you a: Boy or Girl (Circle one)
2. What grade are you in? ____
3. What year were you born? _____

Please circle a number that tells how much you agree or disagree.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. The app Math Tappers helped me to learn to add better .	1	2	3	4	5
5. The app Math Tappers helped me to learn to subtract better .	1	2	3	4	5
6. The app Math Tappers was easy to use.	1	2	3	4	5
7. The app Math Tapper was fun to use.	1	2	3	4	5
8. I would like to use the Math Tappers app again.	1	2	3	4	5

9. What, if anything, did you **like** about using Math Tappers?
10. What, of anything, did you **not** like about using Math Tappers?

Sushi Monster Survey

1. Are you a: Boy or Girl (Circle one)
2. What grade are you in? ____
3. What year were you born? _____

Please circle a number that tells how much you agree or disagree.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. The app Sushi Monster helped me to learn to add better .	1	2	3	4	5
5. The app Sushi Monster helped me to learn to subtract better .	1	2	3	4	5
6. The app Sushi Monster was easy to use.	1	2	3	4	5
7. The app Sushi Monster was fun to use.	1	2	3	4	5
8. I would like to use the Sushi Monster app again.	1	2	3	4	5

9. What, if anything, did you **like** about using **Sushi Monster**?
10. What, of anything, did you **not** like about using **Sushi Monster**?

Prodigy Survey

1. Are you a: Boy or Girl (Circle one)
2. What grade are you in? ____
3. What year were you born? Year: _____

Please circle a number that tells how much you agree or disagree.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. The app Prodigy helped me to learn to add better .	1	2	3	4	5
5. The app Prodigy helped me to learn to subtract better .	1	2	3	4	5
6. The app Prodigy was easy to use.	1	2	3	4	5
7. The app Prodigy was fun to use.	1	2	3	4	5
8. I would like to use the Prodigy app again.	1	2	3	4	5

9. What, if anything, did you **like** about using **Prodigy**?
10. What, of anything, did you **not** like about using **Prodigy**?

Thinking Blocks Survey

1. Are you a: Boy or Girl (Circle one)
2. What grade are you in? ____
3. What year were you born? Year: _____

Please circle a number that tells how much you agree or disagree.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. The app Thinking Blocks helped me to learn to add better .	1	2	3	4	5
5. The app Thinking Blocks helped me to learn to subtract better .	1	2	3	4	5
6. The app Thinking Blocks was easy to use.	1	2	3	4	5
7. The app Thinking Blocks was fun to use.	1	2	3	4	5
8. I would like to use the Thinking Blocks app again.	1	2	3	4	5

9. What, if anything, did you **like** about using **Thinking Blocks**?
10. What, of anything, did you **not** like about using **Thinking Blocks**?

Show Me Survey

1. Are you a: Boy or Girl (Circle one)
2. What grade are you in? ____
3. What year were you born? Year: _____

Please circle a number that tells how much you agree or disagree.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
4. The app Show Me helped me to learn to explain my work .	1	2	3	4	5
5. The app Show Me was easy to use.	1	2	3	4	5
6. The app Show Me was fun to use.	1	2	3	4	5
7. I would like to use the Show Me app again.	1	2	3	4	5

8. What, if anything, did you **like** about using **Show Me**?

9. What, of anything, did you **not** like about using **Show Me**?

Appendix D—Survey: Pre and Post-Tests

Pre-Test for Number Sense and Numeration Unit (Gr.2)

1. Which number is greater? Circle it. 12 78

How do you know it is greater? _____

2. Subtract

76 - 3	40 - 5	83 - 3
42 - 14	65 - 28	75 - 43

3. Add

31 + 2	3 + 24	24 + 7
16 + 98	51 + 96	42 + 12

4. Find a missing numbers.

5 + ____ = 15	____ - 8 = 20	30 - ____ = 6
---------------	---------------	---------------

5. Estimate to add or subtract. Show your work.

$$25 + 9 =$$

$$54 - 35 =$$

6. Circle the correct estimate. Show your work.

$$13 + 59 = 70 \text{ or } 80$$

b. $41 - 15 = 20 \text{ or } 30$

7. Ms. Elms baked 72 chocolate chip cookies for her family. Her daughter wasn't as hungry, so she got 22 cookies. Ms. Elms got the rest. How many cookies did Ms. Elms get? Show your work.

8. Sarah had 47 beads to make a bracelet. She needed 22 more beads. How many beads were on her bracelet altogether? Show your work!

Post-Test for Number Sense and Numeration Unit (Gr.2)

1. Which number is greater? Circle it. 24 86
How do you know it is greater?

2. Subtract

55 - 3	35 - 5	42 - 3
65 - 14	65 - 18	75 - 25

3. Add

31 + 7	5 + 53	74 + 6
23 + 84	84 + 51	51 + 12

4. Find a missing numbers.

3 + ____ = 16	____ - 9 = 24	16 - ____ = 2
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5. Estimate to add or subtract. Show your work.

a. $30 + 8 =$

b. $51 - 12 =$

6. Circle the correct estimate. Show your work.

a. $17 + 52 = 70$ or 80

b. $32 - 15 = 10$ or 20

7. Ms. Kwak baked 42 chocolate chip cookies for her family. Her son wasn't as hungry, so he got 17 cookies. Ms. Kwak got the rest. How many cookies did Ms. Kwak get? Show your work.

8. Maya had 53 beads to make a bracelet. She needed 15 more beads. How many beads were on her bracelet altogether? Show your work!

Pre-Test for Number Sense and Numeration Unit (Gr.3)

1. Which number is greater? Circle it. 112 78

How do you know it is greater?

2. Subtract

476 - 243	120 - 25	783 - 53
142 - 114	65 - 28	975-243

3. Add

531+ 342	193+24	524+ 402
16+ 98	351+ 396	42+ 512

4. Find the missing number.

5+ _____ = 18	_____ - 9 = 20	34- _____ = 5
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5. Estimate to add or subtract. Show your work.

a. $23 + 52 =$

b. $87 - 30 =$

6. Circle the correct estimate. Show your work.

a. $183 + 589 = 700$ or 800

b. $412 - 211 = 100$ or 200

7. Our school has 524 students. There are 210 girls. How many boys are there? Show your work!

8. Nathan's school has a bake sale every year. Last year he sold 824 cookies at the bake sale. This year he sold 142 more cookies than last year. How many cookies did he sell this year? Show your work!

Post-Test for Number Sense and Numeration Unit (Gr.3)

1. Which number is greater? Circle it. 502 259

How do you know it is greater?

2. Subtract

513 - 246	240 - 25	583 - 42
152 - 102	52 - 14	914 - 211

3. Add

621 + 241	145 + 24	514 + 416
25 + 95	261 + 397	53 + 625

4. Find the missing number.

4 + _____ = 17	_____ - 2 = 46	54 - _____ = 8
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5. Estimate to add or subtract. Show your work.

a. $24 + 87 =$

b. $65 - 29 =$

6. Circle the correct estimate. Show your work.

a. $265 + 634 = 800$ or 900

b. $536 - 165 = 300$ or 400

7. Our school has 742 students. There are 466 girls. How many boys are there? Show your work!

8. Noah's school has a bake sale every year. Last year he sold 735 cookies at the bake sale. This year he sold 267 more cookies than last year. How many cookies did he sell this year? Show your work!

Appendix E- Interview Notes

[The interviewer will place the iPad in front of the student and ask them to pick the app that they used in the mathematics unit]

Interview Script:

Teacher: Hi (students' name)! How are you? Please have a seat, (student's name).

I would like to ask you a few questions about whether you liked using __apps, and whether it helped you learn. It is important for teachers to find out the best apps to use in our mathematics class.

Whether you participate or not will have no effect on your marks in this class or school. If you agree to participate in the interview, I am going to record your answers for a research study.

Would you like to participate in this interview?

Teacher: (Prompting questions)

So which apps were the most helpful? (Show me)

Why did you choose these apps?

Were the uses of these iPad apps in the mathematics class helpful? Why or why not?

Did you have any problems or issues using the iPads?

Appendix F – Criteria for Reviewing iPad Apps

EVALUATION RUBRIC FOR IPOD/IPAD APPS

DOMAIN	4	3	2	1
Curriculum Connection	Skill(s) reinforced are strongly connected to the targeted skill or concept	Skill(s) reinforced are related to the targeted skill or concept	Skill(s) reinforced are prerequisite or foundation skills for the targeted skill or concept	Skill(s) reinforced in the app are not clearly connected to the targeted skill or concept
Authenticity	Targeted skills are practiced in an authentic format/ problem-based learning environment	Some aspects of the app are presented in an authentic learning environment	Skills are practiced in a contrived game/simulation format	Skills are practiced in a rote or isolated fashion (e.g. flashcards)
Feedback	Feedback is specific and results in improved student performance	Feedback is specific and results in improved student performance (may include tutorial aids)	Feedback is limited to the correctness of student responses and may allow students to try again	Feedback is limited to the correctness of student responses
Differentiation	App offers complete flexibility to alter settings to meet student needs	App offers more than one degree of flexibility to adjust settings to meet student needs	App offers limited flexibility to adjust settings to meet student needs (e.g., few levels such as easy, medium, hard)	App offers no flexibility to adjust settings to meet student needs (settings cannot be altered)
User Friendliness	Students can launch and navigate within the app independently	Students need to have the teacher review how to use the app	Students need to have the teacher review how to use the app on more than one occasion	Students need constant teacher supervision in order to use the app
Student Motivation	Students are highly motivated to use the app and select it as their first choice from a selection of related choices of apps	Students use the app as directed by the teacher	Students view the app as "more schoolwork" and may be off-task when directed by the teacher to use the app	Students avoid the use of the app or complain when use of the app is assigned
Reporting	Data is available electronically to the student and teacher as a part of the app	Data is available electronically to student on a summary page and may be screenshot to share with teacher	Data is available electronically to the student, but is not presented on a single summary page	The app does not contain a summary page

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