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Analysing the use of mathematics apps in elementary school classrooms

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Abstract

Limited research has been conducted on the use of mathematics apps in elementary school environments. The purpose of this study was to examine student (n = 127) and teacher (n = 6) attitudes toward the use of constructive-based, mathematics apps in Grades 4–6 and to explore what factors influence learning performance. Students rated the design and engagement value of mathematics apps high and the learning value moderately high. Teachers were neutral about app design but rated the engagement and learning value high. Student learning performance increased significantly after using mathematics apps for remembering, understanding, applications and analysis-based tasks. Student gender, ability, attitudes and age had no significant impact on student learning performance. On the other hand, teacher gender and strategies had a significant impact on student learning performance. Students scored 13% higher with female teachers, 24% higher when students used apps in pairs and 21% lower with a teacher-led strategy.

Keywords: Attitudes, elementary school, learning performance, mathematics, mobile apps

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1. Introduction

1.1. Overview

A number of research studies have suggested that students (An et al., 2015; Clark & Luckin, 2013; Riconscente, 2013; vanDeusen et al., 2014) and teachers (Clark & Lucking, 2013; Freebody et al., 2007; Kay & Knaack, 2008) have positive attitudes about using tablets in the classroom and that this use can lead to significant gains in learning (Kumi-Yeboah & Campbell, 2015; McKenna, 2012; Pitchford, 2014). The success of tablets, though, is largely dependent on the quality of implementation and software used (Clark & Luckin, 2013; Freebody et al., 2007; Keengwe, 2013). Consequently, the focus of research has shifted away from focusing on the tablet technology to targeting the use and quality of educational mobile apps. An educational mobile app is an interactive tool that supports learning by enhancing, amplifying and/or guiding the cognitive processes of learners (Kay & Knaack, 2008). In the domain of mathematics, there are at least two types of apps: Practice-based and constructive. Practice-based apps are designed to improve math fluency with basic facts and skills (Hawkins, 2017; Riconscente, 2013) whereas constructive apps support exploration, investigation, constructing solutions and manipulating virtual parameters. Some advantages of using mathematics apps include allowing students to work at their own pace and level, receiving frequent formative feedback, learning in a relatively risk-free environment with multiple opportunities to test their knowledge and connecting visual to symbolic representations (Chang et al., 2013; Moyer-Packenham & Westenshkow, 2013; Zhang et al., 2015). There are at least three gaps in the research conducted on mathematics apps. First, limited systematic research has been conducted on elementary school student and teacher attitudes toward mathematics apps. Second, while a number of studies have examined the impact of mathematics apps on general learning, no studies have examined the impact on acquiring specific types of knowledge (e.g., remembering, understanding, applying and analysing). Third, minimal research has been conducted on factors that might influence the impact of mathematics apps on student learning. The purpose of this study, then, was to investigate student and teacher attitudes toward mathematics apps and to explore what factors influence learning performance.

1.2. Students attitudes toward mathematics apps

At least three factors have been examined with respect to elementary school student attitudes toward mathematics apps: Design, engagement and learning. Regarding design, several studies reported that students found the apps they used to be well designed (Kay & Knaack, 2008) or easy to use (Freebody et al., 2007; Reimer & Moyer, 2005). With respect to engagement, researchers noted that students were engaged, interested and enthusiastic about apps and wanted to use them again (Freebody et al., 2007; Kay & Knaack, 2008; Reimer & Moyer, 2005; Riconscente, 2013). Finally, several papers indicated that students found apps helpful with respect to learning (Freebody et al., 2007; Kay & Knaack, 2008; Reimer & Moyer, 2005; Riconscente, 2013). Overall, only four studies have examined have specifically examined elementary student attitudes toward mathematics apps and only one study (Kay & Knaack, 2008) used a multidimensional, systematic assessment approach.

1.3. Teacher attitudes toward mathematics apps

Only two studies could be found that investigated elementary school teacher attitudes toward apps (Freebody et al., 2007; Kay & Knaack, 2008). Kay & Knack (2008) reported that teachers rated the design value highly for a series of mathematics and science apps used by elementary school students. Teachers also rated the engagement value of elementary level mathematics apps highly in at least two studies (Freebody et al., 2007; Kay & Knaack, 2008). Finally, with respect to learning, teachers claimed that apps helped support the learning of factual content, labelling and definitions, the explorations of and connections and with the application of concepts (Freebody et al., 2007). More specifically teachers believed that the immediate feedback and multiple opportunities to attempts tasks helped students obtain mastery (Kay & Knaack, 2008). Clearly, more research is needed to understand teachers' attitudes toward mathematics apps and their possible impact on student performance.

1.4. Learning performance with mathematics apps

At least nine studies have been conducted on the impact of mathematics apps on student learning (Bulut et al., 2015; Burns et al., 2012; Kong & Kwok, 2005; Moyer-Packenham & Suh, 2012; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005; Riconscente, 2013; Thambi & Eu, 2013; Zhang et al., 2015). All studies used a pre- and post-test, quasi-experimental design to examine the impact of practice-based, game-based or constructive apps. Mathematics concepts address included place value, fractions, ordering decimals, multiplication and graphing. Regardless of app type and concept taught, all studies reported significant increases in student performance with a large average effect size of 0.74. However, no studies examined the impact of apps on different levels of mathematics knowledge such as remembering, understanding, applying or analysing (Krathwohl, 2002). It is conceivable that mathematics apps might influence different kinds of mathematical knowledge.

1.5. *Factors affecting learning performance*

1.5.1. Student factors

Only two student factors have been formally examined with respect to the use of mathematics apps in elementary school classrooms: Student ability and gender. With respect to student ability, at least five studies have indicated that students at-risk or with low mathematics ability show significantly higher gains after using apps than students with higher math abilities (Burns et al., 2012; Nurmi & Jaakkola, 2006; Moyer-Packenham & Suh, 2012; Pitchford, 2014). One study reported no significant difference in learning gains among students with different ability levels after they used mathematics apps. Another study noted that students with higher math ability showed significantly higher gains compared to students with lower ability after using apps.

Regarding gender, a recent Common Sense Media Report (2015) noted that girls used social media more often than boys and boys played games more often than girls. It is possible that gender preference might alter the impact of certain mathematics apps. However, Moyer-Packenham & Westenshkow (2014) reported that there were no significant gender differences in learning when mathematics apps were used.

No research has been conducted on the impact of grade level (age) or student attitudes on the use of mathematics apps in elementary school classrooms. It is possible, though, that older students might be better able to handle the independent learning typically encouraged with constructive-based apps. It is also reasonable to assume that students with positive attitudes toward mathematics apps would perform better than students with negative attitudes.

1.5.2. Teacher factors

An et al. (2015) claim that a teacher's instructional approach is the most important benchmark for student success when using mobile apps. It is not surprising, then, that the most frequently examined teacher factor regarding app use is teaching strategy. There is considerable variation in how teachers choose to use mathematics apps in elementary school classrooms (Freebody et al., 2007; Kay & Knaack, 2008). The most common approaches are teacher-led (An et. al., 2015; Freebody et al., 2007), pair-based (Clark & Luckin, 2013; Freebody et al., 2007) and individual use of apps (Burns et al., 2012; Moyer-Packenham et al., 2008, 2013; Nurmi & Jaakkola, 2006; Reimer & Moyer, 2005; Zhang et al., 2015). To date, no research has been conducted on which of these strategies might work best in terms of student performance. Furthermore, no research could be found regarding the impact of teacher experience and teacher attitudes on learning performance after mathematics apps are used. It is reasonable to assume, though, that either of these two factors might influence student success with apps.

1.6. Research questions

Four research questions were asked in this study:

1. What are elementary school student and teacher attitudes toward the design, engagement and learning value of mathematics apps?
2. What is the impact of mathematics apps on remembering, understanding, applying and analysing mathematical concepts at the elementary school level?
3. What student factors (gender, ability level, grade level and attitudes) influence overall student learning with mathematics apps?
4. What teacher factors (strategy, gender, experience and attitudes) influence overall school students learning with mathematics apps?

2. Methodology

2.1. Participants

Students in this study lived in a suburban region (650,000 people) in Ontario, Canada. One hundred and twenty-seven students (67 males and 54 females) between 9 and 11 years of age, 127 students participated in the study. Students were enrolled in Grades 4 (n = 30), 5 (n = 64) or 6 (n = 43). Most students (n = 92, 88%) agreed or strongly agreed that they were comfortable using computers (M = 4.3 out of 5, SD = 0.7). Almost 60% of the students (n = 54) agreed or strongly agreed that they were good at doing mathematics, however, one-third were neutral about their mathematical ability (M = 3.7 out of 5, SD = 1.0).

Six teachers (3 males and 3 females) with 3–23 years teaching experience participated in the study. Three teachers were born between 1946 and 1964 (Baby Boomers, Tapscott, 2009) and three teachers were born between 1977 and 1990 (Net Generation, Tapscott, 2009).

2.2. Description of mathematics apps used

Five mathematics apps were selected from the Explore Learning Collection (www.explorelearning.com) and focussed on fractions, decimals, percent, probability and stem and leaf plots. Links to the actual apps used and support materials are available at tinyurl.com/WCETR-MathAppList. All apps were exploratory in nature and supported a constructive approach to learning. Each app came with a student exploration sheet to guide student learning.

2.3. Data collection

2.3.1. Attitudes

Student attitudes were assessed using a survey based on the research of Kay & Knaack (2008; 2009) and consisted of 10, five-point Likert scale items focussing on app design (n = 3 items and r = 0.73), engagement (n = 4 items and r = 0.85) and learning (n = 3 items, r = 0.83). Internal reliability estimates were considered acceptable for measures used in social sciences (Kline, 1999; Nunnally, 1978). Teacher attitudes were also assessed based on surveys developed by Kay & Knaack (2008; 2009) and assessed design (n = 5 items), engagement (n = 4 items) and learning (n = 6 items). Internal reliability for the teacher scale could not be determined because of the small sample size. Student learning performance was determined by pre- and post-tests developed by the instructor or provided by the app. The content of each question was rated based on four Bloom's taxonomy levels (remembering, understanding, application and analysis) (Krathwohl, 2002).

2.4. Procedure

All teachers participated in a half-day workshop focussing on the selection, evaluation and use of mathematics apps. All teachers (n = 6) agreed that they were properly trained. The extra time required to prepare for app lesson ranged from 0 to 13 min with an average of M = 2.9, SD = 5.1. All teachers had students use the guides provided by the app. In a typical lesson, a pre-test was given, students used an app with the student guide for 20–90 min (M = 46.7, SD = 24.0), then a post-test was delivered.

3. Results

3.1. Student attitudes toward mathematics apps

Sixty to 70% of elementary school students agreed that the mathematics apps were easy to use and included good graphics and colours (Table 1).

Table 1. Primary school student attitudes toward app design

Factor	Mean (SD) [1]	% Disagree[2]	% Agree[3]
The app was easy to use.	4.0 (1.0)	9	72
The graphics in the app were good.	3.9 (1.1)	13	61
The colours in the app looked good	3.9 (1.1)	17	72

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

Approximately two-thirds of the elementary school students agreed that mathematics apps made learning fun and interesting and that they would like to use the apps again (Table 2).

Table 2. Primary school student attitudes toward the engagement value of apps

Factor	Mean (SD) [1]	% Disagree[2]	% Agree[3]
The app made learning fun.	3.8 (1.3)	13	61
The liked using the app.	3.9 (1.1)	9	71
The app made learning more interesting.	3.8 (1.1)	15	64
I would like to use apps again.	3.8 (1.3)	24	66

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

Almost two-thirds of the elementary school students believed that the mathematics app helped them learn, however, only four out of ten students believed that the graphics and animations helped improve learning (Table 3).

Table 3. Primary school student attitudes toward the learning value of apps

Factor	Mean (SD) [1]	% Disagree[2]	% Agree[3]
The app helped me learn	3.7 (1.2)	14	65
The graphics and animations from the apps helped me learn	3.2 (1.2)	22	40
The app helped me understand the topic we were learning better	3.7 (1.3)	18	58

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

3.2. Teacher attitudes toward mathematics apps

Most teachers in this study rated the design of apps highly. The average score ranged from 4.0 to 4.7 out of five for the five design features rated (Table 4).

Table 4. Primary school teacher attitudes toward app design (n=6)

Factor	Mean (SD) [1]	Disagree[2]	Agree[3]
The app was well organised	4.2 (0.4)	0	6
The app was easy to use	4.3 (0.8)	0	5
Instructions for using the app were clear	4.2 (1.0)	0	4
The app graphics were attractive	4.0 (1.1)	0	5
The app looked like it was professionally designed	4.7 (0.5)	0	6

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

Ratings for the engagement value of apps were similar to the design value with teacher ratings ranging from 4.0 to 4.7 (Table 5).

Table 5. Primary school teacher attitudes toward engagement value of apps (n=6)

Factor	Mean (SD) [1]	Disagree[2]	Agree[3]
The app was engaging for my students	4.7 (0.5)	0	6
The app made learning fun for my students	4.3 (0.8)	0	5
The app was interesting for my students	4.2 (0.7)	0	5
My students were on task when the app was used	4.0 (0.6)	0	5

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

Teachers also rated the learning value of apps high with the average score ranging from 3.5 to 4.7. Feedback offered by the app was the only area of uncertainty for two teachers (Table 6).

Table 6. Primary school teacher attitudes toward learning value of apps (n=6)

Factor	Mean (SD) [1]	Disagree[2]	Agree[3]
The app helped my students learn	4.5 (0.5)	0	6
Graphics/animations from the app helped my students learn	4.7 (0.7)	0	6
Feedback from the app was helpful for my students	3.5 (0.8)	1	4
My student appeared to understand concepts better because of the apps	4.0 (0.0)	0	6
The app was an effective learning tool for my students			
Overall, the app-enhanced student learning in my class	4.5 (0.5)	0	6

[1]Based on a 5-point Likert scale (Strongly Disagree to Strongly Agree)

[2]Combined Disagree and Strongly Disagree

[3]Combined Agree and Strongly Agree

3.3. Student learning performance

Significant differences between pre- and post-test scores were observed for remembering (61% increase), understanding (29% increase), application (23% increase) and analysis (30% increase) questions. Effect sizes ranged from 0.54 to 1.87 reflecting a large difference between pre- and post-test questions (Cohen, 1988). See table 7.

Table 7. Learning performance before and after using apps

Learning Activity	**n**	**% Pre-Test Mean (SD)**	**% Post-Test Mean (SD)**	**% Change Mean(SD)**	**t(df)**	**Cohen's d**
Remembering	23	34.8 (*43.8*)	95.7 (*14.4*)	60.9 (*45.1*)	6.47 (22) *	1.87
Understanding	94	39.0 (*37.0*)	59.6 (*38.3*)	20.6 (*33.4*)	5.99 (93) *	0.55
Application	52	44.6 (*45.1*)	67.8 (*40.4*)	23.1 (*41.5*)	4.03 (51) *	0.54
Analysis	6	33.3 (*20.4*)	62.5 (*20.9*)	29.1 (*24.6*)	2.91 (5) **	1.41

*p < 0.001

**p < 0.05

Factors affecting student learning performance

3.3.1. Student

Four student factors were examined that might affect student learning performance. Gender, math ability, grade level and student attitude were not significantly related to learning performance.

3.3.2. Teacher

Five teacher factors were assessed that might influence student learning performance. Teacher experience and attitude were not significantly related to learning performance. Choice of teaching strategy did have an impact on student learning. Students who worked in pairs when using apps (M = 37.7% and SD = 32.9%) showed significantly higher percent gains in learning performance than students who did not use this strategy (M = 14.0%, SD = 22.3%) (t(92) = 4.10, p < 0.001, Cohen's d = 0.84). In addition, students who did not experience teacher-led use of apps (M=30.8% and SD=30.8%) showed significantly higher percent gains in learning performance than students who were taught with this strategy (M = 10.0% and SD = 23.7%) (t(92) = 2.85, p < 0.01, Cohen's d = 0.76). Finally, teacher gender was significantly related to learning performance. Students who had female teachers (M = 32.1% and SD = 34.8%) displayed significantly higher percent gains than students who had male teachers (M = 19.4% and SD = 23.4%) (t(92) = 2.10, p < 0.05, Cohen's d = 0.43).

4. Discussion

4.1. Student attitudes toward mathematics apps

Limited systematics research has been conducted on elementary school student attitudes toward mathematics apps (Freebody et al., 2007; Kay & Knaack, 2008; Reimer & Moyer, 2005; Riconscente, 2013). This study looked at three distinct attitude constructs: Design, engagement and learning. Students were relatively positive about all three constructs, a result that is consistent with the previous research. However, there were differences among the three constructs. Students rated design and engagement higher than learning. Specifically, students were neutral about the effectiveness of graphics and animations to help their learning. Future researchers might investigate the specific reasons for these rating using focus group or interview data.

4.2. Teacher attitudes toward mathematics apps

Only two previous studies examined elementary teachers' attitude toward mathematics apps (Freebody et al., 2007; Kay & Knaack, 2008). Teachers rated the design, engagement and learning value of mathematics apps high in the current study. These results are consistent with the previous research, although they are more specific. Of note is teacher ratings were consistently higher, on average, then the student ratings. The impact of mathematics apps may have been somewhat lower than the perceived impact reported by teachers. Clearly, it is important to gather this data from both students and teachers. Future research could employ a more qualitative approach to understand attitude differences between students and teachers.

4.3. Impact of mathematics apps on student learning performance

Numerous studies have examined the impact of mathematics app on the learning performance of elementary school students on a wide variety of concepts. Tall studies showed significant gains in learning based on pre- and post-tests. The key difference in this study, is that four different kinds of mathematical knowledge were looked based on Bloom's taxonomy (Krathwohl, 2002). Student performance for understanding, application and analysis tasks increased 23–30%, whereas remembering tasks increased by 61%. Given that the apps were designed to help construct knowledge, it is somewhat surprising that remembering was the knowledge category that improved the most. A more detailed qualitative analysis involving observational data might be useful in linking knowledge gains to specific mathematics app activities.

4.4. Factors influencing learning performance after using mathematics apps

Limited research has been conducted on student factors that might influence learning performance when mathematics apps are used. In this study, gender, grade level, math ability and students attitude had no apparent impact on student learning. One way of interpreting this is that mathematics apps are relatively unbiased and useful for a majority of students.

It is worth mentioning that the results in this study differed from the previous research on student ability (Burns et al., 2012; Nurmi & Jaakkola, 2006; Lin et al., 2011; Moyer-Packenham & Suh, 2012; Pitchford, 2014) where students with the lower ability benefited more than students with the high ability when mathematic apps were used. This discrepancy may partially be explained by the type of mathematics apps used. Based on students and teacher ratings, the apps in this study were of high quality. Furthermore, they focused on helping student constructing knowledge, a task that would equally challenge all math ability levels.

The previous research has not looked at teacher factors that might influence the impact of mathematics apps on learning. It is somewhat surprising that students with male teachers were at a significant disadvantage in this study. However, the sample size was small, so more research is needed to confirm these results. Further research is also needed to examine the specific behaviours of male or female teachers that might influence learning impact.

Considerable variation exists with respect to the strategies used by elementary teachers when integrating mathematics apps (Freebody et al., 2007; Kay & Knaack, 2008). A pairs-based strategy was significantly more effective than a teacher-led strategy when mathematics apps were used with elementary school students. This result is not surprising given that constructive-based apps are designed to help students build knowledge and working in pairs aids in the social construction of knowledge. Demonstrating a mathematical app in front of a class turns a potentially constructive activity into a passive one.

5. Conclusion

This study used a systematic approach to assessing attitudes and learning performance when constructive mathematics apps were used with elementary school students. The results suggested that both students and teacher had positive attitudes toward the design, engagement and learning values of apps, although students were somewhat less enthused. Furthermore, short-term student performance increased for remembering, understanding, application and analysis-based tasks, however, gains for remembering were at this twice as high as the other three knowledge areas. In addition, using constructive-based mathematics apps appeared to be universally effective for all students regardless of gender, grade level, attitudes toward apps and ability level. Finally, using apps in student pairs worked significantly better than demonstrating apps in front of the class. Future research needs to use a more qualitative approach to links specific app features and activities to attitude and learning differences.

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