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Engaging Primary School Students in Mathematics: Can iPads Make a Difference?

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Abstract Research on the impact of the integration of technologies such as iPads on primary students' attitudes and engagement in mathematics is limited. Further, there have been claims that teachers' pedagogical choices can strongly influence the effectiveness of iPads for engaging students in mathematics. This paper presents an investigation of the influence of teaching and learning mathematics with iPads on students' attitudes and engagement in mathematics. The participants in this study were students in a large urban primary school, implementing an iPad program for teaching and learning across the curriculum. Surveys with five-point Likert-type items were used to measure students' attitudes to mathematics. Students from Years 2 to 6 completed the survey at the beginning and end of two consecutive school years. Survey results suggested that iPad use in mathematics has the potential to impact positively on students' attitudes to mathematics. At the end of the second year of the study, semi-structured interviews were conducted with teachers and students. The interview responses confirmed that iPads had a positive influence on students' engagement and attitudes to mathematics, and that the pedagogical approaches utilised by teachers for embedding iPads in their mathematics lessons contributed positively to these outcomes.

Keywords Primary school mathematics · iPads in mathematics · Engagement · Attitudes to mathematics

Introduction

Information and communication technologies (ICT) are widespread in schools and their use in mathematics classrooms is becoming more broad and varied. While such

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technologies have the potential to engage students, research results are mixed and perhaps unsurprisingly, it has been shown that the teacher's pedagogical approaches have a strong influence on the potential of ICT to engage students in mathematics (Attard & Northcote, 2011). Popularity of iPads in schools is continually growing due to their ease of use; mobility; financial accessibility; their capacity to allow students to work in flexible learning environments; and the availability of diverse applications, many of which are cost-free (Ireland & Woollerton, 2010). Despite the continued growth in iPad use in schools, there exists limited research on the learning outcomes of iPad integration generally and in particular, its influence on primary school students' attitudes to and engagement in mathematics (Attard & Curry, 2012).

This paper reports on the first 2 years of a 3-year phased program of iPad integration across a large urban primary school in Queensland, Australia. In the first year of the program, all children in at least one class in each year level, from Prep (the year before Year 1) to Year 6, had their own iPads. The teachers who volunteered to teach these classes also had their own iPads and were provided with substantial professional development opportunities that focused on both technological and pedagogical aspects of iPad integration across the curriculum. The second year of the program mirrored the first, with additional classes in each year level becoming iPad classes. This program represented a substantial financial investment for the school and parents. As such, it was important to investigate a range of student outcomes to determine the effectiveness of iPad integration across the school. This need was the impetus for the 2-year study reported in this paper. The purpose of this paper is to focus specifically on the influence of teaching and learning mathematics with iPads on students' engagement and attitudes to mathematics.

Background

Engagement in Mathematics

The extensive corpus of literature on student engagement is complicated by numerous and nuanced definitions. Indeed, Fredricks, Blumenfeld and Paris (2004) argued that an attempt to synthesise the literature is problematic as it contains a "proliferation of constructs, definitions, and measure of concepts that differ slightly, thereby doing little to improve conceptual clarity" (p. 60). Instead, Fredricks et al. (2004) argued for the usefulness of considering engagement to be a multidimensional construct, or a 'meta' construct that encompasses behavioural, cognitive, and emotional engagement, adding that this may provide a richer characterisation of children's engagement than would a focus on individual components. In considering this tension between conceptual clarity and practicality, Fredricks et al. (2004) argued that the benefit of mixing concepts when measuring engagement might outweigh the loss of conceptual clarity, especially in light of the evidence that engagement is changeable and may be related to context. In response to these arguments and as a result of a review of the engagement literature, Attard (2014) defined engagement in mathematics as the 'coming together' of cognitive, emotional, and behavioural engagement that leads to students' enjoyment and valuing of mathematics (p. 3). According to Attard

(2011), classroom engagement involves active participation and involvement in classroom activities. Since this study focuses on engagement from the students' and teachers' perspectives, Attard's definition of classroom engagement is adopted in this paper.

Influences on Engagement

It has long been recognised that affective issues are central to mathematics teaching and learning (McLeod, 1992). A large body of literature shows that students have increased levels of engagement if they have positive attitudes to mathematics, for example, high mathematical self-perceptions and enjoyment of mathematics (Adelson & McCoach, 2011; Goos, Dole & Geiger, 2012; Linnenbrink & Pintrich, 2003; Pintrich & Zusho, 2002; Usher & Pajares, 2006). Achievement in mathematics has also been found to be positively related to these factors, which adds another imperative to find ways to enhance students' attitudes and engagement in mathematics (Barkatsas, Kasimatis & Gialamas, 2009; Commonwealth of Australia, 2008; Dowker, Bennett & Smith, 2012).

Unfortunately, research has shown that by the time children are in upper primary school, they have developed attitudes to mathematics, which may influence both their engagement and achievement in mathematics (Dowker et al., 2012; Eccles, Wigfield, Harold & Blumenfeld, 1993). Research has also revealed more negative attitudes to mathematics for female students (Frenzel, Pekrun & Goetz, 2007; Larkin & Jorgensen, 2015) and lowered levels of engagement in primary and secondary schooling (Attard & Curry, 2012; Larkin & Jorgensen, 2015). A worrying finding from recent research showed that negative attitudes and disengagement may develop even earlier than previously thought (Larkin & Jorgensen, 2015). Taken together, these research findings suggest that it is important to investigate ways to enhance children's mathematical engagement and their attitudes to mathematics.

Although much is known about attitudes in general and there is much research interest in students' mathematical attitudes in particular, there exist very few studies or psychometrically validated instruments that allow researchers to measure primary school students' attitudes in mathematics (Adelson & McCoach, 2011; Larkin & Jorgensen, 2015). This is of concern given that as early as Year 3 many students have formed perceptions of themselves as learners of mathematics (Adelson & McCoach, 2011). Over a period of several years, Adelson and McCoach (2011) sought to address this need by developing and validating the *Math and Me Survey*, which was designed for use with primary school students from 8 years of age to measure two key aspects of their attitudes to mathematics: self-perceptions and enjoyment. The authors of this instrument defined *mathematical self-perceptions* as "a person's perceptions of self as a mathematical learner, including beliefs about his or her ability to learn and to perform well in mathematics" (Adelson & McCoach, 2011, p. 226). They defined *enjoyment of mathematics* as "the degree to which a person takes pleasure in doing and learning mathematics" (Adelson & McCoach, 2011, p. 44). Their decision to focus on mathematical self-perceptions and enjoyment of mathematics stemmed from the fact that these aspects have not been widely researched and yet they are known to have a strong influence on students' engagement and achievement in mathematics.

Mobile Technology in Mathematics Learning

Given that mobile devices are ubiquitous in students' lives beyond school, it makes sense to identify ways to harness the affordances of these technologies for use in classrooms and to examine their impact on students. Of particular interest is the potential for such technologies to engage students in learning (Donaldson, 2012). Allowing students to use tablet devices is believed to lead to an increase in students' motivation (Kunzler, 2011), and according to Couse and Chen (2010), technology use has a positive impact on students' self-perceptions. However, Attard and Curry (2012) noted the limited evidence about the capacity of iPad integration to enhance primary school students' mathematical engagement. Although engaging students through the integration of technology into mathematics lessons is a growing area of research interest, to date, the research on the impact of technology, and particularly mobile technologies, on students' engagement in and attitudes to mathematics remains quite limited and more research is needed to investigate their impact (Fabian, Topping & Barron, 2016; Handal et al., 2014).

Of the studies that have been conducted, few have focused on the impact of iPad use on attitudes and engagement and even fewer have been conducted in primary school classrooms or in mathematics (see Fabian et al., 2016). The majority of studies have focused on middle to upper secondary school; specific learning activities (e.g. Franklin & Peng, 2008); university level students (e.g. van Oostveen, Muirhead & Goodman, 2011); or on students with particular difficulties, such as emotional disturbance (see Kyanka-Maggart, 2013) or cognitive disabilities (e.g. O'Malley et al., 2013; Shah, 2011). Oliver and Corn (2008) conducted a 2-year study into middle school students' tablet use and found that utilising tablets had a positive influence on students' attitudes and engagement. According to Singer (2015), using mobile devices can provide positive experiences that improve students' attitudes to mathematics. Attard and Curry (2012) conducted a qualitative study during a 6-month trial of iPad incorporation into a Year 3 mathematics classroom and found that integrating iPads into teaching and learning appeared to have a positive influence on the students' engagement; however, they highlighted the need for further investigation into the use of iPads for mathematics and the pedagogies associated with their use.

Teaching Mathematics with Technology

Researchers have emphasised the need for effective pedagogies to accompany the use of technology in mathematics classrooms and have highlighted the different ways in which teachers adopt tablets in their classrooms (see Attard, 2015; Oliver & Corn, 2008). Clearly, it is not sufficient to assume that the mere introduction of technologies, such as mobile tablets, into the mathematics classroom will enhance engagement in mathematics. Indeed, Attard and Northcote (2011) noted that ICT might even have a negative impact on students' engagement in mathematics, for example, if the teaching focuses on the technology rather than the mathematics (for example, learning how to use the device itself rather than using it for learning mathematical concepts). Attard (2013a) also cautioned that the effectiveness of mobile devices, such as iPads, for mathematics learning depends on the types of applications (apps) used, and argued that those based on games or drill-and-practice activities give students few opportunities to use problem solving skills or to reflect on their learning. According to Attard (2013b), when iPad activities do not involve an appropriate level of challenge, students' engagement is limited.

Following a longitudinal study of middle years mathematics students, Attard (2014) devised the Framework for Engagement with Mathematics (FEM) to describe the pedagogies necessary for engaging students in mathematics. She highlighted the potential of mobile tablets for providing new opportunities for teachers to engage students in activities that align with the FEM, which emphasises features of pedagogies that Attard believes necessary for engaging students in mathematics learning, including teachers acknowledging students' backgrounds and learning needs; high levels of student-student and student-teacher interactions; timely and constructive feedback; opportunities for substantive conversations about mathematics; student tasks that are challenging and have an element of choice; embedded technology to promote student-centred learning; and varied tasks that cater for diverse learning needs. According to Attard, these pedagogies go beyond the use of particular resources in the classroom to reflect the level of pedagogical relationships that are essential to promoting students' engagement. Because teachers have a powerful influence on student engagement (Hattie, 2003), it is clear that while iPads have the potential to enhance attitudes and engagement, their influence cannot be considered in isolation of the pedagogies used in the mathematics classroom. It is also important to obtain students' perceptions of their learning environment because these perceptions provide an insight into how the learning environment influences their engagement (Attard, 2011).

Research Questions

The data reported here are from a broader study, which focused on numerous effects of integrating iPads on numeracy teaching and learning across the curriculum. The focus of this paper is on the influence of teaching and learning with iPads on students' attitudes and engagement in mathematics. To fully address this focus, the paper also describes the pedagogical choices of teachers that may have contributed to students' engagement. The research questions addressed are as follows:

1. Is there a difference in attitudes to mathematics of students in iPad and non-iPad classes at the end of either year of the iPad program?
2. What aspects of learning with iPads enhance students' engagement in mathematics?
3. What pedagogical choices regarding the use of iPads in mathematics appear to influence students' engagement in mathematics?

Method

Participants

The participants in this study were students in mixed gender and ability classes from Years 2 to 6 (aged 7 to 11 years) at an urban government school with students from mixed socio-economic backgrounds. This school was chosen because it was embarking on a phased introduction of iPads. In the first year of this introduction (2014), all students in at least one class per grade had a personal iPad, purchased by the child's parents or carers. A total of 405 students from Years 2 to 6 completed a survey at the beginning and end of the school year (264 students in non-iPad classes and 141 students in iPad classes). The numbers of boys and girls were approximately equal. In the second year of the study, an additional iPad class was formed in each grade. A total of 424 students completed the 2015 pre- and post- surveys (118 students in non-iPad classes, 150 students in iPad classes in 2014 and 2015, and 156 students from iPad classes in 2015 only). The iPad classes formed in 2015 contained a mix of students who had joined the program in its first and second years. The teachers who taught iPad classes in both 2014 and 2015 were involved in the study (seven teachers). These teachers were all female, ranging in classroom experience from less than 5 years to over 20 years.

Data Collection

Maths and Me Surveys. The *Math and Me Survey* (Adelson & McCoach, 2011) consists of 18 items used to measure students' attitudes to mathematics (to address Research Question 1). The authors of the survey gave permission for its use. The instrument employs five-point Likert-type items (1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree), with negatively worded questions being reverse coded. Through multiple studies, the authors of the survey conducted content validation, exploratory and confirmatory factor analyses, and reliability and validity analyses to develop the final survey, which consists of two scales: Enjoyment of Mathematics (10 items) and Mathematical Self-Perceptions (8 items). The survey was designed to be appropriate in terms of reading level for primary school children from Years 3 to 6.

Prior to its administration, the participant school leadership team reviewed the survey to ensure its suitability in terms of content and readability. Although iPads were introduced from Prep to Year 6 in the study school, due to readability concerns, it was considered inappropriate to administer it to children in Year 1 and the preparatory year. Class teachers were briefed and given written instructions prior to administration of the survey, which was implemented at the beginning and end of both the 2014 and 2015 school years. Students completed the survey in class with their own teacher, who provided clarification as needed. The time to complete the survey varied from 20 to 30 min, depending on the grade. Across all classes, each survey was administered on the same day each time.

Semi-Structured Interviews. The purpose of the semi-structured interviews was to collect data related to Research Questions 2 and 3. Toward the end of the second year of the program, all iPad class teachers who had been involved for both years and a sample of students from iPad classes were interviewed. The teachers were asked questions about their students' learning and engagement in mathematics with iPads and the teaching strategies and resources employed when iPads were used during mathematics lessons. Interviews were approximately 40 min in length. Ten students (five boys and five girls) were interviewed about learning mathematics with iPads. The questions focused on whether they enjoyed learning mathematics with iPads, whether they felt learning with iPads helped them in mathematics, and the approaches or tools used by their teachers when iPads were utilised in the mathematics classroom. The students came from Years 4 to 6. Three students had joined an iPad class in 2015 while the other seven students had been in an iPad class in both years of the program. The student interviews were about 20 min in length. The selection of students was not entirely random; the school provided the names of students who had returned interview consent forms and students were randomly selected from that list. The researchers had no knowledge of students' achievement levels or backgrounds.

Data Analysis

The Maths and Me Surveys. Factor analysis was conducted on each of the four surveys to ensure that the scales on them aligned with the original scales on the Adelson and McCoach (2011) instrument. Having established that this was the case, the Cronbach's alpha value for each set of surveys was calculated to ensure internal consistency of the scales on each instrument. Analyses of variance (ANOVA) were used to make comparisons between groups on each pre- and post-survey administered. Comparison within groups from pre- to post-surveys in each year utilised *t* tests. The use of parametric statistics was considered appropriate in this case because the scores from items were combined to create mean scores for each of the two scales. According to Norman (2010), while scores on Likert items are ordinal, Likert scales, which consist of sums across multiple items, can be considered interval and the use of parametric statistics in this case is both justified and robust.

The Semi-Structured Interviews. The interview data that are presented in this paper relate to student engagement and the pedagogical approaches of teachers. All interview responses were transcribed verbatim. They were analysed using NVivo software to code the data into themes. To address Research Question 2, the responses that were coded into themes relating to student engagement were selected and analysed further to identify specifically how the affordances of iPads promoted students' engagement. Attard's (2014) FEM was used to code the responses of both teachers and students to address Research Question 3. To ensure the internal validity of the qualitative analysis, coding in all steps was undertaken independently by two researchers. Outcomes were compared and discussed, with re-coding where necessary until agreement was reached (Cohen, Manion & Morrison, 2000).

Results

Maths and Me Surveys

Factor Structure. In 2014, the initial factor analysis was conducted with all 18 items. The principal component analysis, completed with Varimax rotation, produced a solution that aligned with the original survey and consisted of two factors, with the items associated with each being the same as those identified by Adelson and McCoach (2011) (i.e. Factor 1: Enjoyment of Mathematics and Factor 2: Mathematical Self-

Perceptions). One item had a factor loading of less than .4 and did not load more strongly on one factor than the other. Following the rule of thumb that items with a loading of less than .4 should not be retained (Brace, Kemp & Snelgar, 2009; Thompson, 2004), this item was omitted from the 2014 survey used in this study. After omission of this item, component analysis was repeated (again with Varimax rotation) for the pre- and post-surveys. The final items and the results of the second component analysis are shown in Table 9 in Appendix A. This procedure was repeated for the 2015 pre- and post-surveys, but in this case, all 18 items were retained. The results of the component analysis for the 2015 surveys are shown in Table 10.

Table 1 reports on total variance explained for each factor on the surveys. Increasing the number of factors did not increase the explanatory power in the case of any of the surveys. Table 1 also shows Cronbach's alpha values for each scale and overall values for each administration of the survey. These values indicated reasonable to high internal consistency for all items within each factor. The Cronbach's alpha values for the overall surveys indicate a high overall reliability for all four surveys.

The Pre-2014 Survey. When the responses of students in the non-iPad and iPad cohorts on Scale 1 (Enjoyment of Mathematics) and Scale 2 (Mathematical Self-Perceptions) were compared using *t* tests, there were no significant differences. When the data were split by sex, there was a significant difference between the boys and girls in the iPad cohort on the Mathematical Self-Perceptions scale ($t = 2.222$, $df = 140$, $p < .05$, two-tailed). As shown in Table 2, while both boys and girls in the iPad cohort were reasonably positive in their responses to this scale, boys had higher mathematical self-perceptions than girls. There were no significant differences for the non-iPad cohort. There were no differences between boys in iPad and non-iPad classes, nor were there any for the girls in these different cohorts.

The Post-2014 Survey. Once again, *t* tests were used to compare the responses on each scale on the post-2014 survey. Responses of students in the non-iPad and iPad

Table 1 Total variance and reliability coefficients for each survey

Survey	Scale	Total variance explained (%)	Cronbach's alpha
Pre-2014	Enjoyment	40.0	.83
	Self-Perceptions	8.7	.79
	Overall	48.7	.88
Post-2014	Enjoyment	51.6	.93
	Self-Perceptions	10.9	.89
	Overall	62.4	.94
Pre-2015	Enjoyment	46.5	.91
	Self-Perceptions	8.8	.87
	Overall	55.3	.93
Post-2015	Enjoyment	53.5	.92
	Self-Perceptions	10.2	.92
	Overall	63.6	.94

Table 2 Mean scores for Mathematical Self-Perceptions for boys and girls in the iPad cohort

Sex	*N*	Mean	Standard deviation
Boys	72	3.77	.92
Girls	69	3.45	.80

cohorts on Scale 1 (Enjoyment of Mathematics) and Scale 2 (Mathematical Self-Perceptions) were compared and there were no significant differences between the two cohorts. On the post-2014 survey, there were no significant differences between boys and girls in either cohort on either scale. Examination of the data for the students in the iPad cohort revealed that the boys' self-perceptions remained higher than those of the girls but that the means for the two groups were closer together.

When the responses were compared for boys and girls separately, there were significant differences between boys in the iPad and non-iPad cohorts on both scales: Scale 1 (Enjoyment of Mathematics) (t = -2.010, df = 210, p < .05, two-tailed); Scale 2 (Self-Perceptions) (t = −2.200, df = 210, p < .05, two-tailed). The means and standard deviations are shown in Table 3. (While data were not significantly different for the pre-2014 survey, pre-survey results are included to illustrate differences between the groups). These differences did not exist for the pre-survey, nor were there any differences between iPad and non-iPad girls on either survey. Examination of the means shows that while the mean response for the boys in iPad classes did not change from pre- to post-survey, the mean response for the boys in the non-iPad classes dropped and these means were significantly lower than the boys in the iPad classes on the post-survey.

Pre-Post 2014 Survey Comparison. Comparison of the pre-2014 and post-2014 survey responses revealed a significant difference between the non-iPad cohort's responses of the on the Enjoyment scale (t = 2.030, df = 262, p < .05, two-tailed). The mean scores on this scale revealed a decrease in the enjoyment of mathematics for the students in the non-iPad cohort. These data are shown in Table 4.

There were no significant differences pre- to post-2014 survey on either scale for the iPad cohort. When the data were split by sex, there were no significant differences for girls or boys from pre- to post-2014 survey.

Table 3 Mean scores for boys in iPad and non-iPad cohorts on the pre- and post-2014 surveys

Scale	Class	*N*	Post-survey[a]		Pre-survey	
			M	SD	*M*	SD
1. Enjoyment of Mathematics	iPad	72	3.87	1.09	3.82	1.03
	non-iPad	140	3.54	1.19	3.78	1.10
2. Mathematical Self-Perceptions	iPad	72	3.72	.79	3.77	.91
	non-iPad	140	3.44	.99	3.58	.95

[a] Only post-survey means are significantly different

Table 4 Mean scores on Enjoyment of Mathematics for the non-iPad cohort

Survey	Mean	Standard deviation
Pre-2014	3.74	1.00
Post-2014	3.57	1.06

The Pre-2015 Survey. Comparison among the non-iPad; 2015-only iPad; and 2014 – 2015 iPad cohorts was carried out using ANOVA. There were no significant differences among whole cohorts or when the data were split by sex.

The Post-2015 Survey. As for the pre-2015 survey, ANOVA was used to compare the responses of the three cohorts for each scale on the post-2015 survey. The results revealed a significant difference on the Self-Perceptions scale ($F_{(2,\ 421)} = 3.229$, $p < .05$). Employing the Bonferroni post-hoc test, significant differences were found between the non-iPad cohort and the 2014 – 2015 iPad cohort ($p < .05$) with the mean for the iPad cohort being significantly higher than that of the non-iPad cohort. Means and standard deviations are shown in Table 5.

Similar analysis by sex revealed no significant differences among the three cohorts for the girls on either scale; however, there was a significant difference for the boys on the Enjoyment of Mathematics scale ($F_{(2,\ 207)} = 3.321$, $p < .05$). Employing the Bonferroni post-hoc test, significant differences were found between the boys in the non-iPad cohort and the boys in the 2014 – 2015 iPad cohort ($p < .05$) with the mean of the iPad cohort again being significantly higher than that of the non-iPad cohort. These data are shown in Table 6.

Comparison of boys and girls in each cohort using *t* tests showed that there was a significant difference between the responses of the boys and girls in the 2014 – 2015 iPad cohort on the Enjoyment of Mathematics scale ($t = 1.981$, $df = 148$, $p < .05$). The means and standard deviations are shown in Table 7. There were no significant differences for the other cohorts on either scale.

Pre-Post 2015 Survey Comparison. There were no significant differences from pre- to post-2015 for any cohort.

Semi-Structured Interviews

This section presents the results of interview response analysis in two sections. First, the responses related to student engagement are presented. This is followed by common

Table 5 Mean scores on Self-Perceptions for the non-iPad and 2014 – 2015 iPad cohorts

Cohort	*N*	Mean	Standard deviation
Non-iPad	118	3.47	.98
2014 – 2015 iPad	150	3.75	.87

Table 6 Mean scores on Enjoyment of Mathematics for boys in non-iPad and 2014 – 2015 iPad cohorts

Cohort	*N*	Mean	Standard deviation
Non-iPad	62	3.45	1.26
2014 – 2015 iPad	73	3.95	0.99

themes that relate to teachers' pedagogical approaches when using iPads in mathematics. All respondents are identified using pseudonyms.

Engagement. The responses of all students indicated high levels of engagement in mathematics classes when using iPads. The following section describes themes that reflect the ways in which the affordances of iPads and apps promote engagement. The first of these is the capacity of iPads to provide an element of novelty and challenge. The following student talked about having fun, being more interested, and feeling challenged,

> I really like learning maths with iPads—it's fun—it's like a challenge that's fun at the same time. …Because some of the things are hard but we get to use our iPads or work with others with the mini whiteboard, it's more fun. There's not really much I don't like but I really think I'm more interested. (Carol, Year 6 student, 2014 – 2015 iPad cohort)

This comment reflects engagement in terms of enjoyment and motivation but it also suggests a level of cognitive engagement with challenging tasks.

A second theme centred on the capacity of iPads activities to be individualised (e.g. students can choose the level of difficulty), which enhances students' sense of ownership:

> I love ShowBie [an iPad app] because we get different level tasks for different people. It's good because I'm higher than some of the other kids in the class … we get to work on harder tasks while the others don't have exactly the same level. It leaves you with a challenge and it makes you more attached to your work. (Sharon, Year 6 student, 2014 – 2015 iPad cohort)

The following response suggests that iPads help to maintain the engagement level of students who might otherwise not be so engaged: 'I think iPads are good for all kids. I think it's maybe even better for kids who don't do so well or who aren't so motivated because it helps them with their learning' (Nancy, Year 4 student, 2015 iPad class).

Table 7 Mean scores on Enjoyment of Mathematics for boys and girls in the 2014 – 2015 cohort

Sex	*N*	Mean	Standard deviation
Boy	73	3.95	.99
Girl	77	3.60	1.16

The students were also enthusiastic about the level of variety and choice offered within apps: 'The thing I like about it is that it's something different instead of just with a book. You get to lots of different things and I feel that I have much more control over my learning because we have more choice' (Luke, Year 5 student, 2014 – 2015 iPad cohort). This comment suggests that the element of choice when learning with iPads engages students and promotes self-direction.

The teachers too were effusive about the levels of student engagement that they perceived in their students. While they acknowledged that iPads were sometimes used for drill and practice, particularly in mathematics, providing students with choices within and among apps and providing opportunities for problem solving and creativity were linked to increased levels of engagement:

> I suppose there is a lot of drill and practice but we've just done assessment for multiplication using Keynote and Pages and it was very creative. The kids were so totally engaged. … They're engaged in 'How can I show this?' 'What can I do that enhances what I'm doing?' 'Will I use photos or just words?' (Rachel, Year 3 teacher)

This comment also suggests that the capacity of iPads to allow students to learn through and with multimodalities and to use multiple modes when creating their own products is a strongly engaging factor.

Other comments highlighted the capacity of iPads to engage students, even when using drill and practice applications because of the immediate feedback provided by the apps: 'They are engaged in learning—with the Mathletics program, they can actually see their points, and with Skoolbo—they can monitor their achievement as they go along, so they're getting feedback straight away on the apps they're working on (Tamsin, Year 2 teacher).

Several teachers' comments reflected the notion that iPads can help to engage a diverse range of students, including those with special needs because of the multiple levels offered within apps. In some cases, particularly boys, the element of competition also played a role in engagement. For example,

> I have a little student who is possibly II [intellectually impaired] and he will engage more with the iPad that without. He just sits with a piece of paper but when he's using the iPad, he's still developing the concepts but he's not switching off so I do find that for the lower level learners, it can be helpful. Equally, those students who are at the upper end will come and talk about their results and try to improve. You can see them trying to push themselves further and trying to do better all the time so I would say iPads engage a wide variety of learners. Boys appear to be more into the technology than the girls—even when entering the classroom at the beginning of the day—they're straight on them. Girls like them too but boys are more driven to look at their results and to try to outdo each other, to compete with one another. (Tamsin, Year 2 teacher)

Pedagogical Approaches. Several themes emerged from the student and teacher interviews that reflected the pedagogical approaches identified in the FEM and listed earlier in this paper. In the interests of brevity, these are summarised in Table 8 with representative quotes. The codes indicate how many students or teachers made comments under each theme and the number of comments made, for example, S: 7(9) means that seven students made a total of nine comments under the given theme.

Discussion

The majority of students in all cohorts had quite positive attitudes to mathematics at the beginning and end of each year, although in some cases, the standard

Table 8 Common interview themes, frequency of response, and sample responses for each theme

Teacher awareness of abilities and learning needs T: 6(9); S: 4(4)
I see so many benefits—I think for lower achieving children, perhaps they're more visual—and they have progressed faster using iPads than I thought possible. It helps them communicate their understanding—the iPad is a great tool for that. Some of the children have communication issues—they might know it verbally but they can't put it on paper so the iPad gives them a tool to help them communicate their thinking. (Fiona, Prep Teacher)
Student-student and student-teacher interactions and substantive conversations T: 7(7); S: 7(9)
There's a lot of sharing—there's something on the iPad called Airplay and it connects to the interactive whiteboard and we can see our iPad on the screen so we can explain what we did for others in the class. (Brian, Year 6 student 1, 2014 – 2015 cohort)
Feedback to students T: 6(9); S: 5(5)
Our teacher puts our work on ShowBie and we can do it and click 'done'. That lets her check it when she gets home. (Mark, Year 4 student 2, 2014 – 2015 cohort)
When we're finished those tasks, our teacher gets our work and she can check if we get them right or wrong and that's fun' (Brian, Year 6 student 1, 2014 – 2015 cohort)
Variety of tasks T: 7(9); S: 6(10)
I really like the Mathletics app and Targeting Maths—they're really good to help you learn because with both of them you can do a variety of maths things. Targeting Maths lets you do numbers, shapes and patterns, money, data and you can also do it timed … I think everyone in our class really likes being in the iPad class because it's different instead of just learning—there are lots of tasks and variety. (James, Year 6 student, 2014 – 2015 cohort)
Opportunities for challenge and choice T: 7(8); S: 8(14)
At the beginning of the year we just used a few apps but now they have five choices so they can decide which one they're more comfortable with or that will help them best with what they're doing. It was lovely to see my SEP [Special Education Program] child—the first time she just sailed through the task and she's a child with a lot of anxiety—but now she's comfortable about what she's using and that she understands and that's powerful. (Rachel, Year 3 Teacher)
Student-centred use of technology T: 7(15); S: 9(13)
We have an app called Explain Everything and you can put everything there—you can put photos, record your voice—it's like a slideshow thing so you can explain and record your voice while you're moving things on the screen to explain your thinking. I do think I learn more. There's an app called Khan Academy and it's like this maths academy that posts videos about each topic in maths and you can look at them and then put what you learned into your own presentation to explain it yourself—to represent it in your own way. (Brad, Year 6 student, 2014 – 2015 cohort)
Differentiation/Catering for diverse learners T: 7(11); S: 6(12)
It's great because I can differentiate so much more. For example, I can give all students the same tasks but the higher kids can be working with three-digit numbers while the others are on two-digit numbers—it's so much easier to challenge them at the right level (Carolyn, Year 2 Teacher).

deviations are relatively high. The quantitative data collected to address Research Question 1 also reveal a number of differences in enjoyment of mathematics and mathematical self-perceptions between and among students in iPad and non-iPad cohorts. At the beginning of study, the girls in the iPad cohort had significantly lower mathematical self-perceptions than did the boys. This aligns with previous findings in the literature that boys generally have higher mathematical self-perceptions than do girls (e.g. Barkatsas et al., 2009; Kyriacou & Goulding, 2006; Preckel, Goetz, Pekrun & Kleine, 2008). This pattern was the same for the students in the non-iPad cohort, although the difference was not significant. At the end of 2014, the difference between the iPad cohort boys' and girls' self-perceptions was no longer significant, which may suggest that membership in an iPad class was beneficial for enhancing the girls' mathematical self-perceptions. Since much of the existing literature about girls and attitudes to technology or mathematics shows that they have more negative self-perceptions in mathematics and lower confidence in using technology to learn mathematics areas than do boys (e.g. Barkatsas et al., 2009), this is an interesting finding.

Another interesting difference was noted in the first year of the study between the boys in the iPad cohort and boys in the non-iPad cohort. At the beginning of the study, there was no significant difference between the boys' mean responses in either cohort on either scale. However, at the end of 2014, they differed significantly on both scales and in both cases, the attitudes of the boys in the non-iPad classes were less positive than those of the boys in the iPad classes. Closer inspection of the results for the iPad boys indicates that while being in the iPad classes for a year did not improve their attitudes, which were already generally positive, their attitudes were maintained. This contrasts with the results for the boys in non-iPad classes whose attitudes became less positive over the course of the year. This finding may indicate that participating in an iPad class has the effect of helping to maintain boys' positive attitudes to mathematics. Similarly, the pre-post comparison data for 2014 suggest that learning mathematics with iPads has a positive influence on students' enjoyment of mathematics. The students in the iPad cohort maintained similar scores on the Enjoyment scale, while the non-iPad cohort was significantly less positive at the end of the year. These findings align with those in the literature regarding the positive influence of tablet devices on students' attitudes (e.g. Kunzler, 2011; Oliver & Corn, 2008).

When the data for 2015 were examined, all significant differences occurred between the non-iPad cohort and the cohort of students who had been in the iPad program for 2 years. There were no significant differences for the 2015-only cohort. This trend may indicate that membership in an iPad class over a longer period of time has a greater influence on students' attitudes. At the beginning of 2015, the second year of the program, there were no significant differences on either scale among the cohorts; however, at the end of the year, the 2014 – 2015 iPad cohort had significantly more positive scores on the Self-Perceptions scale than did the non-iPad cohort. Likewise, the boys in the iPad cohort had significantly more positive scores on the Enjoyment of Mathematics scale. This contrasts with the girls in the 2014 – 2015 iPad cohort. Their scores on the Enjoyment scale remained similar across the 2 years but were significantly less positive than the boys at the end of 2015. As with the 2014 data, these data suggest that membership in iPad classes promotes positive mathematical self-perceptions for both girls and boys and also promotes boys' enjoyment of mathematics.

In summary, learning mathematics with iPads in this study had a positive influence on students' mathematical self-perceptions and boys' enjoyment of mathematics; however, the results are somewhat modest. Nevertheless, while the use of iPads does not appear to have had a strong effect on improving children's attitudes in the short term, there were several significant differences at the end of the second year between the students who had not been members of an iPad class and those who had been in the iPad program for 2 years. Perhaps this finding is related to the fact that students who have negative attitudes are likely to have developed them over several years and it may be unrealistic to expect that the use of iPads in the short term would impact significantly on their attitudes. At the same time, for the iPad cohorts, attitudes from pre- to post-survey in each year did not decrease significantly, which suggests that membership in an iPad class helped to maintain students' positive attitudes.

Research Question 2 focused on the students' and teachers' perceptions of the influence of learning with iPads. It is clear from both teachers' and students' responses to the interview questions that both groups perceived iPads as having a very positive influence on attitudes and engagement. The affordances of iPads enhance students' engagement because of novelty, challenge, and variety within apps; the ability for students to work at an appropriate level; personal control over learning; multimodalities; and immediate feedback. The students described learning with iPads as fun, enjoyable, or exciting, while acknowledging that the tasks were sometimes challenging. They also talked about having more control and being self-directed, and they enjoyed getting immediate feedback from the apps. They also talked frequently about being able to show their thinking, choose the ways in which they could do this, and they were very positive about the capacity of the iPads to allow them to collaborate or share with their classmates. These comments suggest multiple reasons for students' heightened levels of engagement.

The teachers and students perceived that using iPads in mathematics had a positive influence on engagement in the classroom. From the teachers' perspectives, there was a great deal of talk about engagement. All teachers felt that their students were more engaged, with several teachers talking about the capacity of iPads to engage particular students more effectively than traditional lessons might. They noted that for certain students iPads are particularly powerful for supporting students' learning. These students included special education students, low ability students, and students needing extension. The majority of teachers mentioned that they felt the boys in their classes were more engaged than they might otherwise be. Several students echoed this perception. Several girls also talked about how much they felt the boys enjoyed learning with iPads. The boys who were interviewed were enthusiastic about learning with iPads and gave many reasons for this, including being able to compete with other students or to try to improve on their own previous scores on certain apps; however, a commonly mentioned reason for both boys and girls being engaged in mathematics when using the iPads was the amount of control and choice they felt they had over their learning. Many students and teachers spoke about drill and practice or gaming apps and their potential for engagement. The teachers felt that using Targeting Maths and Mathletics allowed students to engage in skill development and practice in a more enjoyable way than simple rote learning. Indeed, these perceptions were echoed by the students who often mentioned these apps as being enjoyable, allowing them to set goals, gain instant feedback, monitor their progress, and compare their progress with other students. These comments are counter to the claims made in literature that the use of such apps don't allow students to reflect on their learning or that they may not challenge or engage students (e.g. Attard, 2013b).

Research Question 3 aimed to elaborate on the teachers' pedagogical choices regarding iPads that impacted on students' engagement in mathematics. As has been argued by Mishra and Koehler (2006), introducing technologies is not sufficient in itself to bring about change in students' outcomes or teachers' practices. Teachers need to make a long-term commitment to learning when and how technology should be included in teaching and learning processes (Goos & Bennison, 2008; Pierce & Ball, 2009). According to Noyes (2012), students are more likely to have positive attitudes to mathematics when student-centred approaches are used. Having established that the students and teachers perceived levels of engagement in mathematics to be greater when using iPads, in order to address Research Question 3 and determine whether the differences between iPad and non-iPad cohorts are due to the use of iPads themselves or whether they are also related to the use of iPads prompting the teachers to use different pedagogies, it is necessary to further consider the interview data.

Certainly the interviews with teachers and students revealed that the teachers had changed their approaches to teaching mathematics and that their mathematics classes were characterised by student-centred learning. When the data were analysed in terms of pedagogical approaches, there was a close alignment with Attard's (2014) FEM. There were recurring comments that reflected a strong student-centred approach, which was characterised by teachers responding to individual students' needs; frequent opportunities for student-student and student-teacher interaction; timely and constructive feedback; substantive conversations about mathematical thinking; opportunities for students to be challenged and to make choices in their learning; and differentiated learning opportunities. Teachers utilised the affordances of different apps (such as iTunesU and Showbie) to differentiate learning, to cater for individual needs, to provide scaffolding for students who needed learning support or access to extension materials for advanced students, and to provide opportunities for students to revisit material about which they were unsure. They also devised activities to promote self-directed learning and student choice, to encourage collaboration and discussion among students, and to challenge students. There was a high emphasis on sharing and on making students' thinking visible and this was frequently mentioned by students as well as teachers. The teachers identified apps that provided a range of modes through which students could show their learning and students were free to choose the mode through which they created assessment products.

It should also be mentioned that the teachers didn't see iPads as a cure-all. They were very aware that the iPads should be viewed as one of a number of tools for learning mathematics and all were quick to emphasise that iPads are not used all the time, with continued emphasis on using concrete materials, developing students' social and fine motor skills, promoting class discussion, and recognising that there were other 'non-iPad' ways for students to show their understanding. Perhaps the most telling response by teachers was that they were unanimous in that they would never go back to teaching without iPads because of the enhanced opportunities for teaching in ways that supported and challenged their students. In the words of the e-learning support teacher (also a Year 3 teacher),

> I wouldn't have it any other way. How could I go back to just pencil and paper—or even just laptops? The advantage of iPads is immediacy—you don't want kids wasting time. In saying that, if I want to achieve something and it doesn't align with the affordances of iPads, they don't get used. It's not about busy work and occupying kids, it's about productive learning.

Conclusion

The data in this study suggest that the use of iPads in mathematics has a positive influence on students' engagement and their enjoyment of and self-perceptions in mathematics. The teachers who were involved with the iPad classes received ongoing professional development that focused on integrating iPads into teaching and learning, and while the approaches used by individual teachers varied from class to class, at the end of 2 years, there were distinct patterns and common themes in the ways in which they described pedagogical choices and decisions about when and how to use iPads in the mathematics classroom. More detailed discussion of these findings is beyond the scope of this paper; however, the results indicate that there was indeed ongoing and very deliberate consideration about how iPads could benefit students and that students' engagement and attitudes to mathematics were promoted by the use of iPads for teaching and learning.

The school's implementation program has been a learning journey, one that was embraced by the teachers and the students. There continues to be ongoing professional development and sharing of ideas among the teachers; however, changing practice for teachers can take time and perhaps there will be more significant differences evident in future years. As the school embarks on the final year of its iPad integration program, it remains to be seen how or whether the current teachers change their practices further and whether there are more pronounced differences between outcomes for the children in their second or third years of iPad classes and those who are new to the program.

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Appendix. Factor Analysis for the Maths and Me Surveys

Table 9 Factor analysis for 2014 pre- and post-surveys

Variable (with item number indicating order on survey)	Pre-survey		Post-survey	
	Enjoyment	Self-Perceptions	Enjoyment	Self-Perceptions
2. I love maths	.711		.730	
4. Maths is boring[a]	.713		.737	
6. I enjoy doing maths puzzles	.653		.739	
10. Maths is fun	.443		.811	
11. I look forward to learning new maths	.754		.773	
13. I hate maths[a]	.724		.742	
14. I enjoy playing maths games	.535		.710	
16. I enjoy studying maths	.650		.777	
18. Solving maths problems is fun	.765		.815	
1. I am really good at maths		.666		.690
3. I understand maths		.677		.720
5. I can solve difficult maths problems		.613		.748
7. Maths is very hard for me[a]		.465		.734
9. Maths is confusing for me[a]		.503		.641
12. Maths comes easily to me		.747		.742
15. I can tell if my answers make sense		.574		.576
17. Doing maths is easy for me		.729		.806

[a] Negatively worded items were scored in a reverse way. $N = 405$

Table 10 Factor analysis for 2015 pre- and post-surveys

Variable (with item number indicating order on survey)	Pre-survey		Post-survey	
	Enjoyment	Self-Perceptions	Enjoyment	Self-Perceptions
2. I love maths	.727		.772	
4. Maths is boring[a]	.604		.729	
6. I enjoy doing maths puzzles	.741		.752	
8. I do maths puzzles just for fun	.468		.665	
10. Maths is fun	.789		.831	
11. I look forward to learning new maths	.729		.793	
13. I hate maths[a]	.635		.508	
14. I enjoy playing maths games	.659		.635	
16. I enjoy studying maths	.751		.794	
18. Solving maths problems is fun	.780		.808	
1. I am really good at maths		.670		.731
3. I understand maths		.678		.745
5. I can solve difficult maths problems		.722		.716
7. Maths is very hard for me[a]		.685		.730
9. Maths is confusing for me[a]		.562		.756
12. Maths comes easily to me		.696		.772
15. I can tell if my answers make sense		.637		.711
17. Doing maths is easy for me		.747		.805

[a] Negatively worded items were scored in a reverse way. $N = 423$

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