Longitudinal study on impact of iPad use on teaching and learning

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Abstract: iPads are so ubiquitous now that one sometimes forgets that they came onto the scene and into schools only very recently in 2010. Hence, there is relatively little empirical data of their impact on teaching and learning. This paper presents the findings of a 3-year study undertaken in an all-girls' secondary school that piloted the use of the iPad through a project called Prototype 21st Century Class (P21C2). The project was launched with four classes in 2011 before scaling up to half the school by 2013. In this study, empirical data through lesson observation was triangulated with perception surveys and group interviews of both teachers and students. It was found that the use of iPad was associated with more learner engagement and collaboration. It also found that the P21C2 pioneers, particularly the low and high ability groups, performed better than their peers in the year-end examinations.

1. Introduction
Much has been written and said about how today's young learners are growing up surrounded by information technology and digital media. This is the generation that does not know a world without 3G phones (available from 2001), Facebook (from 2004), YouTube (2005) and smart phones (2007). Prensky (2001) calls them the Digital Natives and exhorts schools to invent Digital Native methodologies to engage them. Some of his recommendations involve giving them convenient access to information and learning resources because Digital Natives are used to searching for information

ABOUT THE AUTHOR
Hui Yong Tay joined the Curriculum, Teaching and Learning (CTL) Academic Group as a lecturer at the end of 2013. In the many years serving in secondary schools prior to joining CTL, she was variously English and Literature teacher, HOD (EL), dean (Curriculum) and vice-principal. Her research interests grew out of her line of work: her MEd thesis looked into role conflict experienced by HODs; her PhD focused on self-regulated learning and authentic assessment, important areas to her as driver of the curriculum in her school. Above all, she is interested in all things that will enhance student’s learning experience in school. This led to the present study looking into how technology can be used to enhance student outcomes.

PUBLIC INTEREST STATEMENT
Schools are often resistant to the adoption of mobile devices like the iPads in teaching and learning. This could be because empirical research on the impact of its use has been scant, especially research that looks at its impact across a few years. This study hopes to fill this gap with a three-year study undertaken in an all-girls’ secondary school that piloted the use of the iPad across different subject areas. It gathered data through lesson observation, perception surveys and group interviews of both teachers and students. The findings that the use of iPad was associated with more learner engagement and collaboration; and a differentiated effect on different ability groups, should be of interest to all who want to bring about positive student outcomes.
online whenever they are in doubt. Prensky also suggests opportunities for peer collaboration as Digital Natives “function best when networked” (p. 2).

The advent of iPad offered opportunities for making such methodologies a reality. Unlike desktops which necessitated trips to the computer laboratories, the mobility offered by the lightweight iPads made the Internet access to online resources readily available wherever the lessons took place. Also unlike the laptop, the iPad had an extended battery life far beyond the usual school hours. That, along with its short boot-up time and stability against crashes, made the iPad a preferred learning device to be used within schools. Lastly, the intuitive touch-interface presented an ease of use that is key to the successful adoption of any learning device (Milrad & Spikol, 2007). In short, the ready and reliable access to learning support and course material through a mobile, user-friendly personal device meant greater opportunities for learner-centred pedagogies.

It was with the intention of increasing learner-centred pedagogies that the iPad was introduced in 2011 into the school involved in this study. The iPad initiative stemmed from a belief that the possibilities offered by technology will help the students keep engaged and excited about learning. For example, with the personal device at hand, students will have ready access to online resources, including the World Wide Web for real-time information. Students can also take advantage of Web 2.0 tools for online collaboration and feedback. Initially, in 2011, the iPads were loaned to the students in four pilot classes to be used for the whole range of academic subjects and students were allowed to bring them home, even during school holidays. They were returned to the school at the end of the academic year. However, when the project was upscaled, the iPads were purchased and owned by the learners themselves to be used as a personal learning device.

2. Review of literature

The iPad has been used in studies with children as young as two (Geist, 2012). Researchers reported how preschoolers were engaged in math and science content (Aronin & Floyd, 2013) or showed higher quality of peer talk and hands-on engagement (Kucirkova, Messer, Sheehy, & Panadero, 2014). The finding of greater student engagement is a common theme even with other age groups: elementary (Culén & Gasparini, 2011), high school (Ward, Finley, Keil, & Clay, 2013) or university (Manuguerra & Petocz, 2011; Wakefield & Smith, 2012). Though there lacks a consensus on the construct of student engagement (Appleton, Christenson, & Furlong, 2008), the present study delimits student engagement in learning in terms of cognitive engagement, behavioural engagement and affective engagement (Furlong & Christenson, 2008).

Apart from learner engagement, another theme in the literature on the use of the iPad focuses on how the iPads in class facilitated group discussions because of the ready access to research and reading material (Geist, 2011) and collaborative work among peers (Beach, 2012; McMinn & Li, 2012).

Educators have long known the positive effects brought about by group discussions and peer collaborations: from engaging students in the inquiry process (Hammer, 1995), to more learning at higher level (Garside, 1996), and enhanced understanding after considering other people’s perspective (Roehling, Kooi, Dykema, Quisenberry, & Vandlen, 2011). It can also contribute formative feedback to teachers about the students’ understanding (Cirillo, 2013). The research also suggests that the same positive effects can be found even if the discussions were not face to face. Some studies have found that students’ active participation in online discussions contributed significantly to final student results (Palmer, Holt, & Bray, 2008) and greater self-efficacy (Lineweaver, 2010).

More evidence of the positive effects of student discussions can be seen in research into flipped classroom, so-called because the content traditionally delivered in school is set as homework (often through videos), while class time is dedicated to discussions and problem-solving. Researchers have found that this change in lesson activity from teacher talk to more active student involvement resulted in more student involvement and ownership of their learning (Herreid & Schiller, 2013; McLaughlin et al., 2013) and deeper dialogue that went beyond facts to debates (Hoffman, 2014).
The effects of classroom discussion appear to apply differently to different ability groups (Kahn, 2007). In a meta-analysis of empirical studies conducted to examine the effects of classroom discussion on students’ comprehension of text, researchers found discussions had more effect on students of below-average ability than for students of average or above-average ability (Murphy, Wilkinson, Soter, Hennessey, & Alexander, 2009). One possible explanation suggested was that students of higher ability levels already possess the skills needed to comprehend and so did not need the discussion as much. Looking at the literature on the impact of the iPad on student outcomes, there have been few studies to date that investigated any differentiated effect on different ability levels. One such study by Sheppard (2011) looked at the percentage change in Knowledge, Comprehension and Analysis scores of 43 Year 6 students (boys aged 11–13) after a reading intervention using iPads. They reported that of the three ability groups, only the Low group showed positive growth in Analysis. However, like the other two ability groups, they did not show improvement in Knowledge and Comprehension.

Perhaps, to have an idea of the iPad on children with different abilities, one can look up various studies on the use of iPads by students who do not characteristically do well in conventional school setting. In one particular case study involving students with Attention Deficit Hyperactivity Disorder, comparisons of pre- and post-assessments showed that participants had gained one year’s growth in reading within six weeks (McClanahan, Williams, Kennedy, & Tate, 2012). In another study involving three high school students with emotional disturbance, researchers compared the use of worksheets with the use of an iPad on math fluency and active academic engagement, and found that with the iPad, participants solved more math problems correctly in less time and demonstrated higher levels of active engagement (Haydon et al., 2012).

In summary, the literature suggests that the use of iPad has resulted in greater student engagement and more student-centred class activities, particularly class discussions. However, there have been few studies on the differentiated effect of the iPad on different ability levels.

3. Research questions
The present study was conducted to explore the effects of the iPad on teaching and learning. Specifically, it sought to address the following research questions:

(1) Did the use of the iPad result in a change in student’s engagement in learning?
   • Did the level and nature of engagement change across the years?
   • Did the level and nature of engagement differ across age groups?
   • Did the engagement change the nature of student’s learning?

(2) Did the use of the iPad result in a change in lesson activities?
   • Did the level and nature of engagement change across the years?
   • Did the level and nature of engagement differ across age groups?

(3) Did the use of the iPad result in a difference in student outcomes, particularly with different ability groups?

The findings would add valuable data to the current limited pool of empirical research on the impact of the iPad in education. In particular, the longitudinal data would also give a much deeper insight than is available in the literature so far.

4. Method

4.1. Participants
The site of the current study is at an all-girls’ secondary school (ages 13–16). Students enrolled are mostly from middle- or upper middle-class background. They are high ability, among the top 10 per cent of their age group based on their t-scores from the national examinations they sat for before enrolling in the present school.
The study started in 2011 when the school launched Prototype 21st Century Class (P21C²), piloting the use of the iPad for teaching and learning in four classes: two classes Secondary 1 cohort (13-year-old) and two Sec 3 cohort (15-year-old). For the rest of the study, the former will be referred to as Lower Sec P21C² pioneers, while the latter will be referred to as Upper Sec P21C² pioneers. In the following year, the programme was not continued for the Upper Sec P21C² pioneers when they proceeded to Sec 4. The main reason was that it was their final year before proceeding to Years 5 and 6 in the partner school, where there was no such one-to-one computing programme. In contrast, the school upscaled the project to the whole Secondary 2 cohort in 2012 (total of 420 students in 13 classes). The whole Sec 2 cohort continued with the programme when they progressed to Sec 3 in 2013.

4.2. Procedure
To answer Research Question 1 on student engagement, self-report surveys were administered every year to all students who were on the P21C² programme. To understand the longer term impact, both students and teachers who had been on the programme since it was launched were invited to give their views through semi-structured group interviews for students and online survey (for teachers). In this study, student engagement in learning is operationalized in terms of:

- learning more deeply (cognitive engagement),
- extending learning outside formal class time (behavioural engagement),
- participating in collaborative work with peers (affective engagement).

To answer Research Question 2 on change in lesson activities, direct observation was made of how the iPads were used in a sampling of classes. For a few weeks in the school year, a research assistant was stationed at the back of the classroom with a stopwatch to clock the amount of time spent on various class activities: teacher talk (disseminating information), group/class discussions and others.

With respect to Research Question 3 on student outcomes, the data used were from the students’ year-end examination scores.

In short, the study was designed as mixed study research involving both quantitative and qualitative data, with the intent that the results of one would help to elaborate or illustrate the results of the other. For example, the qualitative data can help explain any relationship that emerges from the quantitative data.

4.3. Data collection and analysis
As can be seen from the previous section, data were collected from three different sources. The first involved findings from perception surveys and interviews. Each year, an online survey invited students to answer the following questions on a five-point Likert scale (5 for strongly agree, 4 for agree, 3 for neutral, 2 for disagree, 1 for strongly disagree):

- I find lessons using iPad more engaging.
- I find I learn more things/more deeply with the use of the iPad.
- My learning extends outside of class time with the use of the iPad.
- I have more opportunities to collaborate with my classmates over schoolwork with the
- Generally, I would recommend the use of iPad in other levels.

The data were analysed to see if there were differences across levels and over the years. An alpha level of .05 was used for all statistical tests.
The findings were triangulated against the group interviews conducted at the end of 2013 when the Lower Sec P21C\textsuperscript{2} pioneers were interviewed to talk about their classroom experiences over the last three years on the programme. The semi-structured interview schedule focused on the following questions:

- What were the things made possible with the iPad over the last three years?
- How has learning changed over the last three years? Give examples.
- Overall, has the iPad enhanced learning over the past three years?

The qualitative data were transcribed and then analysed for recurring themes, especially with respect to levels and types of engagement in learning.

Data from teachers came from an online survey conducted at the end of 2013. The participants were among the teachers who had been involved in the iPad project for at least two years.

Secondly, empirical data came from lesson observations starting in 2011, when data were gathered from the four pilot classes involved in the iPad project. The control group then comprised select classes on the same level taught by teachers who also taught the P21C\textsuperscript{2} classes or teachers who matched them in competency and subject area. In 2012 and 2013, there was no external control group since all classes on the cohort were involved in the project. So observation data were classified in terms of when the iPad was used and when it was not during the lesson.

Lastly, the academic results of the P21C\textsuperscript{2} students were tracked. Results of the Upper Sec P21C\textsuperscript{2} pioneers were analysed in 2011 when they had been on the programme and also in 2012, even though they were no longer in the programme. It was partly because many of the participants had bought their own iPad and continued to use it as a personal learning device; and partly because the study wanted to probe to see if there were any residual effects from the programme. The results of Lower Sec P21C\textsuperscript{2} pioneers were analysed for 2011 as well as subsequent years though by then, the programme had been upscaled to include all in the cohort. The intent was to see if there was any difference in results of these students who had been on the programme longer than their peers. Because the iPad was used across subject areas, the indicator for academic results used was the mean subject grade (MSG) that is the average of all the grades in the subjects taken by the student. It is to be noted that the grades range from A1 (best) to F9 (worst). Hence unlike the grade point average, MSG is such that the lower the better, with the best-possible MSG being at 1.

One possible confounding factor taken into consideration while analysing the students’ results was the effect from their abilities. In this study, the measure used as indicator of their ability was the t-score (i.e. Transformed Scores) achieved at the national examination at the end of their primary school education. Higher t-scores suggest higher ability. The two-factor ANOVA was used to test the main effects of the two factors (P21C\textsuperscript{2} and ability) as well as any interaction between the two.

To test if the P21C\textsuperscript{2} intervention had a differentiated effect on different ability groups, the students were grouped by their t-score into lower quartile, median and upper quartile; and the results of each group were analysed for any significant difference.

5. Findings
The results of data analysis are organized around the main research questions:

1. Did the use of the iPad result in a change in student’s engagement in learning?
2. Did the use of the iPad result in a change in lesson activities?
3. Did the use of the iPad result in a difference in student outcomes, particularly with different ability groups?
5.1. Did the use of the iPad result in a change in student’s engagement in learning?

5.1.1. Student perception in 2011

As seen in Figure 1, the survey showed that from those who responded to the survey, Lower Sec P21C² pioneers (n = 57) responded more positively compared to the Upper Sec P21C² pioneers (n = 35) in rating their learning to be more engaging, deeper and more collaborative. The only question where they lagged was in the use of the iPad to extend their learning outside of class time. Detailed descriptive statistics for this figure and all other figures in the present study can be found in Appendix A.

Independent t-tests were used to find if the differences in perception were statistically significant. It was found that there was significant difference only in the area of engagement (t = 2.13, df = 86.776, p < .05) and whether they recommended the iPad to other levels (t = 3.07, df = 88.75, p < .05). The items associated with aspects of engagement were not statistically different: Learn More Deeply (t = 1.31, df = 90, p > .05), Learn Extends Outside Class (t = −1.46, df = 90, p > .05) and Collaboration (t = .82, df = 90, p > .05).

However, the remarks offered by the respondents in the survey helped shed light in which specific areas students found learning with the iPad more engaging. The Lower Sec students, more often than the Upper Sec, mentioned how “different apps and techniques for lessons” enhanced “the level of interest in the class”. Another remarked how in addition to the “useful apps” they used in class, they also explored “very interesting and useful” apps on their own. This theme of learning outside of class was common to both Lower Sec and Upper Sec respondents because they often commented on the easy access to online resources:

The iPad is very convenient and has helped make learning more engaging and convenient for me. It also cuts down on waiting time, for example, if I wanted to do some research for a project I do not have to wait until I get home or recess to get to the computer, I can make use of the time in between classes when the next teacher has not arrived. (Lower Sec respondent)

The Upper Sec respondents mentioned that it “really does help in (their) learning, by being able to find stuff online immediately when (they) do not understand / know, and it really aids in the understanding of lessons” and how the iPad was “useful in researching on topics that cannot be found in textbooks”.

In short, the convenient access to information and resources afforded by the iPad had enabled participants to learn more or learn more deeply beyond class.

It is to be noted that generally, the Upper Sec P21C² pioneers did not recommend the use of the iPad in other levels. Their comments seemed to suggest a concern about lagging behind others in some subjects because “the teachers may spend too much of curriculum time with the class experimenting with the iPad’s educational functions”. Another respondent summarised her view as such:
With the vast advancement of technology today, I feel that the launching of the pilot program introduces an entirely different approach for our learning in an unbounded environment. However, I personally believe there were certain activities where the iPad was needed which were not entirely in line with our syllabus despite the time constraints to cover what was needed for the school terms. I thought that it might be more appropriate for the juniors to have an opportunity to have a feel of this program as well but maybe not so ideal for the Sec 4s.

5.1.2. Student perception over the three years 2011–2013

Figure 2 shows the rising positive ratings over the years despite the increased number of participants: from the four select classes (2011) to the whole Sec 2 cohort (2012) and subsequently, both Sec 2 and 3 cohorts (2013). Given that the scale ranged from 5 for strongly agree, 4 for agree, 3 for neutral; the results show generally a positive indication of more engaged and cognitive, behavioural and affective aspects of engagement (deeper learning, extending outside of class time with more collaboration, respectively).

Figure 3 compares the response from the same cohort—their response when they were in Sec 2 (2012) and a year later, when they were in Sec 3 (2013). It appears that they became slightly more positive in 2013. However, independent t-tests showed that there was no significant difference in their responses.

Again, the qualitative remarks helped to understand which specific aspect of engagement impacted the students. Like in the previous year, there were comments on how “information can be
easily accessed through iPads” or how much easier it was to “access to notes of every subject without having to carry all of them around”. Another respondent mentioned that she found “the use of iPad good as we get to collaborate with our classmates over schoolwork more”.

5.1.3. Difference across cohorts and age groups

Figure 4 compares the response from two different Sec 2 cohorts. Independent t-tests showed that the 2013 Sec 2’s perception was significantly higher than their seniors in all areas surveyed: Engaged Learning (t = −4.85, df = 253, p < .05); Learn More Deeply (t = −3.07, df = 228.91, p < .05) Learning Extends Outside Class (t = −2.67, df = 253, p < .05), More Opportunities to Collaborate (t = −4.73, df = 253, p < .05), Recommend P21C² to Other Levels (t = −4.73, df = 253, p < .05).

Not only were the 2013 Sec 2 more positive in their response compared to the 2012 cohort, they appeared to be more positive than their Sec 3 seniors in that year (see Figure 5). Moreover, independent t-tests showed statistically significant difference in two areas: Engaged Learning (t = 3.79, df = 204, p < .05); and Recommending P21C² to Other Levels (t = 4.24, df = 204, p < .05).

Analysis of the qualitative remarks shows how the mobility afforded by the iPad helped in extending their learning outside class for both levels but also the older girls’ concern about the easy access to other distractions on the iPad:

The iPads are useful as they make learning more efficient. We can do our homework on the bus while we are on the go, instead of looking for a window which we can write on. Also, it is easier and more convenient to research for articles and so on. (Sec 2, 2013)
I think using the iPad sometimes keeps us more engaged since we can make use of applications to facilitate our learning when we are not in school (although this may not exactly be a good reason for introducing the use of the iPad since we can do the same with computers from home). However, the iPad gives students easy access to social media sites, which can easily pose distractions. This would not be a major problem if teachers could properly monitor activity on iPads during lessons, but since it is impossible to monitor this all the time, I think the distractions that using the iPad poses could be considered before recommending it to Sec 1s and 4s. (Sec 3, 2013)

Despite the misgivings, the 2013 Sec 3 had significantly higher ratings than their 2011 counterparts in every area surveyed (see Figure 6): Engaged Learning ($t = -4.06, df = 117, p < .05$); Learn More Deeply ($t = -4.47, df = 117, p < .05$); Learning Extends Outside Class ($t = -2.51, df = 49.26, p < .05$); More Opportunities to Collaborate ($t = -2.63, df = 46.913, p < .05$); Recommend P21C² to Other Levels ($t = -2.11, df = 117, p < .05$).

5.1.4. Semi-structured group interview
Out of the 58 students who have been in the in the P21C² programme since 2011, 42 students participated in the semi-structured group interview based on the following questions:

What were the things made possible with the iPad over the last three years?
How has learning changed over the last three years? Give examples.
Overall, has the iPad enhanced learning over the past three years?

Their response confirmed the themes highlighted earlier on the impact on their learning because of the immediacy afforded by the iPad in getting information on demand: one said, “I am glad that I can immediately go to the internet and google and bolster my understanding of the topic” while another commented, “We can like look up on information immediately if we don’t understand anything. It is helpful to get information right away at the moment”.

The availability of online resources enabled more self-directedness. They spoke of taking “the initiative to look things up”. One spoke candidly about how if she did not pay attention in class, she would look it up online. Another said that even if something was not covered in class, they could “immediately access and study it (them)selves. Like, (they) need to find out for (them)selves”. Some felt they were also “reading the news more often” and “more engaged with things around the world”.

As a consequence, the role of learner and teacher had changed. In one participant’s words, previously, “it was a crisis without (a) teacher”, now “You can go online. Everything is there, e.g. YouTube”. Though one participant thought that this resulted in less incentive to pay attention in class since one
could read it up later, another felt that “For learning of concepts, you can go online. To get help to select material, you need help from teachers”. Another participant saw the teacher as a “source of clarification”. Many spoke of how convenient it was to get help or explanation from the teacher via email or online platforms. One participant reiterated “It is good sometimes that we don’t rely too much on the teachers. It is quite good”.

Learning had also become more collaborative because it was now “convenient to share information with one another more easily”. Participants felt that there was “a lot of discussion” on platforms like Edmodo and googledocs where they learnt from one another through the “to and froing of conversation”.

Another development was their interaction with the iPad over the years. They spoke of how in the earlier days, they were “unfamiliar with the iPad and (they) got distracted a lot”. Now they were “more focused” and searched for “more Apps that are more effective” for their learning. Others said that “In Sec 2 iPad was something fun and convenient and a cool factor, now it is more a tool”, to be used “only for study”. One participant commented that ironically because it was a distraction, “The iPad has helped me be more disciplined”. One point that would have helped was for adults to trust them in their use of the device, for example, teachers who “empower (them) with self control” and for parents to accept what they were doing on the iPad.

Overall, the participants unanimously agreed that the use of the iPad had enhanced their learning, making them more self-directed and collaborative.

5.1.5. Teacher perception
At the end of 2013, seventeen teachers who had at least two years of experience on the P21C2 programme were invited to participate in an online survey. Thirteen (76%) responded to the survey. Generally, the participants agreed or strongly agreed that the programme had led to learning that was more engaged, deeper, extended beyond class and collaborative (see Figure 7).

Their written comments also helped to shed light on how the iPad was used to engage students. The teachers specifically mentioned apps that helped students deepen understanding, for example, the use of mindmapping apps (for example, Popplet and Mindmeister) and production tools (such as iMovie and Keynote) for creating animations for teachers to facilitate understanding as well as for students to demonstrate grasp of concepts. iTunes U was also mentioned as “a great platform as a central repository for subject materials” and it also offered opportunities for self-assessment through the inbuilt widgets that gave feedback on students’ answers.

Teachers also highlighted the use of online platforms such as Edmodo and Todaysmeet to encourage students “who are less vocal” to contribute as well as for teachers to check understanding. One teacher mentioned how students “authentic work” gleaned from online discussion was used later in class to “address the actual challenges that the students faced”.

![Figure 7. Teachers' response to online survey on the effect of the use of iPad on student learning.](image-url)
As shown in Figure 8, they also largely agreed or strongly agreed that the programme brought a new dimension to their lesson design. It was noted that the new element in lesson most mentioned by the teachers was promoting collaborative work among students. One teacher commented that students were just beginning “to see the value/power of sharing”, while another commented that “some students who were reluctant to contribute views and thoughts are now more able and willing to do so”.

In addition, it offered opportunities for developing students’ twenty-first century skills. For example, though iPads allow easy access to a wealth of information, students need “information and literacy skills on how to evaluate and use information to construct their own knowledge as necessary skills”. One respondent noted that “apps and technology (that) allow students to make their learning and thinking visible encourage meta-cognition, thinking about (their) own learning and processes”. However, it is not all rosy. The tension posed by the conventional paper-and-pen assessment mode was evident in one comment: “If our high stakes national exams remain what they are, the skills and competencies we hope to achieve with technology seem misaligned. The old methods are still the most efficient (and most effective) way of producing results”. Still, out of the 13 respondents, 3 (23%) felt that the iPad was useful as a teaching and learning tool while 8 (61.5%) rated it very useful and 2 (15.4%) rated it extremely useful.

One possible reason for their positive response is their perception that students had become “more self-directed” with “more control over their learning”, being able to “access resources anywhere anytime”. Students were more independent and “they don’t need the teacher to tell them what to learn”. Specifically, through flipped classroom lessons, teachers need not “repeat the explanation many times” but the approach also enabled students “to watch the videos and read supplementary readings conveniently, ask questions without the need to wait for the following day” and also “to work collaboratively in class and to ask questions instead of going through content in class”.

5.2. Did the use of the iPad result in a change in lesson activities?

5.2.1. Difference in lesson activities over the years

In the first year, it was observed that there was slightly more teacher talk in the P21C2 classes. However, it was not statistically different ($t = .84, df = 87, p > .05$). From observation, the greater teacher talk could partly be attributed to teachers giving instructions on how to use the iPad and to answer student enquiries on the use of apps. There was no statistically significant difference in amount of teacher talk between the Lower and Upper Sec P21C2 pioneer classes ($t = .21, df = 57, p > .05$).

In the subsequent two years, there appeared to be a fall in teacher talk, with less percentage of teacher talk during class time when the iPad was used (see Figure 9). However, the difference was
not statistically significant for both 2012 ($t = -0.68, df = 42, p > .05$) and 2013 ($t = -1.65, df = 123, p > .05$).

There was however a notable difference in the amount of group discussions between the times when the iPad was used and when it was not (see Figure 10).

In 2011, there was more percentage of lesson time spent on group discussions but not statistically significant ($t = -0.09, df = 87, p > .05$). There was no statistically significant difference between the Lower and Upper Sec P21C\textsuperscript{2} pioneer classes ($t = 0.67, df = 57, p > .05$).

In the following years, as shown in Figure 10, there appeared to be much more time spent on group discussions when the iPad was used compared to when it was not. However, data analysis showed that the difference was not significant in 2012 ($t = 2.01, df = 14.17, p > .05$) but in 2013, time spent on group discussion was significantly higher when the iPad was used ($t = 5.84, df = 48.73, p < .05$).

Figure 11 illustrates the amount of teacher talk and group discussion when the iPad was used in Sec 3 class across the years. Analysis showed that there were statistically significant lower percentage of teacher talk in 2013 compared to 2011 ($t = 2.27, df = 44, p < .05$) and statistically higher percentage of group discussion in 2013 compared to 2011 ($t = -3.15, df = 20.29, p < .05$).

As with Research Question 1, the data for Research Question 2 were also analysed to see if there was a difference in lesson activities due to cohorts (as they progressed through the years) or across different age groups. The analysis found:

- No statistically significant difference in time spent in teacher talk for lessons when the iPad was used in Sec 2 across 2012 and 2013 ($t = 0.29, df = 35, p > .05$)
• No statistically significant difference in time spent in group discussions when the iPad was used in Sec 2 across 2012 and 2013 ($t = -0.34, df = 35, p > .05$)

• No statistically significant difference in Sec 2 (2013) and Sec 3 (2013) teacher talk when the iPad was used ($t = -1.54, df = 38, p > .05$). It was similar for group discussion ($t = -1.59, df = 38, p > .05$).

At that point in 2012, it was observed that increasingly much of the classroom discussions spilt over to the online sphere, particularly with the set-up of many class and subject accounts on Edmodo, a secure social network with many Facebook-like features such as post message, discussion threads. As such, data were gathered at one single point in time to study the nature of students’ posts on Edmodo. Analysis of the posts found that slightly more than half of the posts were indeed extensions of class discussions or collaborative work among peers (see Figure 12).

5.3. Did the use of the iPad result in a difference in student outcomes, particularly with different ability groups?

5.3.1. Across the years
The mean subject grades suggest that P21C$^2$ pioneers did better (with lower MSG) than their peers, both for the Lower Sec (Figure 13) and Upper Sec (Figure 14).

Analysing 2011 student results using ANOVA, with ability as covariate, showed there was a significant difference between the MSG of Lower Sec P21C$^2$ pioneers and their cohort ($F = 5.33, p < .05$). There was also significant difference in interaction between the two factors, P21C$^2$ and ability, ($F = 4.88, p < .05$). In the following year, there was significant effect from the iPad factor ($F = 5.172, p < .05$) and ability ($F = 102.06, p < .05$) and interaction effect ($F = 4.70, p < .05$). However, by 2013,
there was no significant effect due to P21C2 ($F = 1.59$, $p > .05$) nor interaction ($F = 1.48$, $p > .05$) while ability ($F = 69.85$, $p < .05$) continues to significantly influence their results.

Similar Anova tests on the results of the Upper Sec P21C2, with ability as covariate, showed no statistically significant difference for P21C2 factor in 2011 ($F = .25$, $p > .05$) and in 2012 ($F = .35$, $p > .05$).

5.3.2. Across ability groupings
Since the previous data analysis found that there was an interaction effect between P21C2 and ability, the students were also grouped by their $t$-score into lower quartile, median and upper quartile group in order to study if the iPad intervention had a differentiated effect on each of these groups of students. Table 1 shows the distribution of students in each ability grouping.

Figure 15 shows the 2011–2013 results of the Lower Sec P21C2 pioneers as better than their peers’, across all ability groups. Independent $t$-tests showed that in 2011, there was significant difference in two groups: the low ($t = −3.28$, $df = 132$, $p < .05$) and the high ($t = −3.92$, $df = 59.90$, $p < .05$) but not for the median group ($t = −.80$, $df = 126$, $p > .05$). The findings of the analysis of their 2012 results were consistent with 2011: statistically significant difference in the lower quartile group ($t = −3.17$, $df = 132$, $p < .05$) and high ability group ($t = −3.39$, $df = 48.06$, $p < .05$) but not the median group ($t = −1.16$, $df = 126$, $p > .05$). The 2013 year-end results show patterns similar to previous years, though not as pronounced as before. Independent $t$-tests showed no statistically significance in all

| Ability grouping | Low | Median | High |
|------------------|-----|--------|------|
| P21C2            | 16  | 18     | 23   |
| Others           | 118 | 110    | 107  |
Figure 15. Comparing academic results of Lower Sec P21C\(^2\) pioneers with the rest of their cohort across the years.

Note: For mean subject grade (MSG), a smaller number indicates better results, with 1 being a perfect score.

Table 2. Number of Upper Sec students in each ability grouping

| Ability grouping | Low | Median | High |
|------------------|-----|--------|------|
| P21C\(^2\)      | 16  | 22     | 19   |
| Others           | 93  | 153    | 94   |

three groups: low (\(t = -1.68, df = 131, p > .05\)), median (\(t = -0.52, df = 126, p > .05\)) and high (\(t = -1.59, df = 128, p > .05\)).

The same types of analysis were applied to the results of the Upper Sec P21C\(^2\) participants across 2011 and 2012 (see, Table 2 for distribution among ability groupings).

Figure 16 shows slightly better results for the Upper Sec P21C\(^2\) pioneers (lower MSG). However, all independent t-tests did not show up any statistically significant difference for all ability groups in 2011: low (\(t = -1.09, df = 107, p > .05\)), median (\(t = .31, df = 173, p > .05\)), high (\(t = -0.71, df = 112, p > .05\)) and 2012: low (\(t = -0.27, df = 106, p > .05\)), median (\(t = -0.23, df = 173, p > .05\)), high (\(t = -0.17, df = 111, p > .05\)).
6. Discussion
The present study sought to investigate whether a 1–1 computing programme (P21C) using iPads would have an effect on student engagement, lesson activities and student outcomes. Data were gathered from perception surveys, lesson observations and student year-end examination results. Because data were gathered across three years, the study offered an opportunity to detect trends. The key findings are highlighted in Table 3.

Data from surveys found that the students consistently reported that they found lessons using the iPad more engaging. Details of what specifically they found engaging were found in the themes gleaned from qualitative remarks in the surveys each year as well as the group interviews of students who had been on the programme for three years: they were now able to access information or learning resources whenever they needed it. Learning was now also more collaborative because by lesson design or due to online connectivity, they could easily tap into a network of fellow learners.

One could argue that access to online resources and discussions (both on and off-line) was not due to the iPad per se. The same effect would have been achieved through any other device such as desktop or laptop. While this is a valid point, the mobility afforded by the lightweight iPad with extensive battery life was probably what enabled the students to report that they could use it throughout the day, and even on the bus on their way home. As mentioned before, usability is a key factor in successfully leveraging on such devices in teaching and learning (Milrad & Spikol).

It is also noted that the response was more positive with the younger students. Hence in considering the effect on the students, one should perhaps not discount the novelty factor, particularly when the iPad was first introduced to the students when it was new on the market and very sought after. One respondent also alluded as much to this when she said, “I was quite excited in Sec 1, as the iPad was quite novel, but now everyone has one, so it gets boring”. This probably accounts for the

| Table 3. Summary of key findings |
|---------------------------------|
| **Comparing within cohort of that year and across cohorts (if applicable)** |
| **Comparing across years** |
| Research Question 1: Did the use of iPad result in a change in student engagement in learning |
| - Generally positive indication of engagement and elements of engagement: deeper learning, extending outside of class time with more collaboration. |
| - Lower Sec P21C2 pioneers reporting significantly more engaged learning than Upper Sec Pioneers. |
| - Sec 2 (2013) reported being more engaged and more recommended the programme to other levels, compared with Sec 3 (2013) |
| - A rising trend in ratings in all areas surveyed |
| - Sec 2 (2013) more positive than their 2012 counterparts in all areas surveyed. |
| - Sec 3 (2013) more positive than Sec 3 (2011) in all areas surveyed. |
| - More-self-directedness (from qualitative data) |
| - More collaborative learning (from qualitative data) |
| Research Question 2: Did the use of the iPad result in a change in a change in lesson activities? |
| In comparing when iPad was used and when it was not, there was |
| - no statistically significant difference in amount of teacher talk (2011, 2012, 2013); |
| - no statistically significant difference in amount of group discussion in 2011, 2012 but significantly higher in 2013.Comparing across cohorts, |
| - No statistically significant difference in amount of teacher talk between the Lower Sec and the Upper Sec P21C2 pioneer classes. |
| - No statistically significant difference in amount of group discussion btw Sec 2 and Sec 3 (2013), |
| Comparing data when the iPad was used in class, |
| - no statistically significant difference in amount of teacher talk or group discussions between Sec 2 (2012) and Sec 2 (2013); |
| - significantly less teacher talk and greater group discussion at Sec 3 in 2013, compared to Sec 3, 2011. |
| Research Question 3: Did the use of the iPad result in a difference in student outcomes, particularly with different ability groups? |
| For Lower Sec Pioneers, significantly better results for low and high ability groupings in 2011, 2012 but not in 2013.No statistically significant difference in Upper Sec for all ability groups (2011, 2012). |
| Significantly better results for Lower Sec Pioneers compared to their cohort peers in 2011, 2012 but not 2013.No statistically significant difference in the results of the Upper Sec Pioneers (2011, 2012). |
distraction mentioned in the respondents’ qualitative remarks. However, as the students reported, once the novelty wore off, the device became a tool for learning.

The other explanation for the higher engagement levels with the younger students could be explained by with how the iPad was or rather, not used by the teachers in the Upper Sec. There is some indication that the iPad was not used as effectively nor pervasively as in the Lower Sec with remarks such as “Our Sec 3 teacher did not use the iPad as much” or that “some teachers don’t use iPad much except for Keynote”. Even then, as reported earlier, the 2013 Sec 3 ratings of their engagement in every area surveyed were significantly higher than their 2011 counterparts. This, along with the significantly higher ratings of the 2013 Sec 2 cohort over the 2012 Sec 2 cohort, suggests that the teachers were getting more skilled in the use of the iPad in their teaching. Increasingly, they were not just using the apps available but repurposing them to get students to demonstrate critical and meta-cognitive thinking. An example was how a teacher used Video Physics, an app which instantly creates velocity graphs from a video of a moving object. Instead of getting students to create graphs using the app, the teacher presented students with various displacement–time graphs and challenged them to hypothesize the movement of the object that could have resulted in the given graphs. Thereafter, students worked in groups to test their hypothesis by recreating the movement live and using the app to see if the graph generated matched the ones given by the teacher.

Classroom observations attested to how the iPad had brought a new dimension in lesson design. For example, teachers set up online mindmaps that could be edited simultaneously so that students could work collaboratively and to give peer feedback on each other’s work. Assessments also took on a new form with production tools (such as iMovie and Keynote) used as ways for students to demonstrate their understanding. One example was in a Geography lesson when students watched a silent iMovie animation on tectonic plate movements. Then they worked together to tape a voice-over to accompany the animation, hence demonstrating their grasp of the target concepts.

The case for the teachers’ change in pedagogy would have been more convincing if the classroom observation results had shown a significant difference, which was largely not the case as the findings had shown. However, it could be that the findings were limited by the design of the study that had measured only the discussion as taking place in the physical class, when in fact, some of the class and group discussion had migrated online. As such, future studies in this area would do well to heed the advice by Sharples, Arnedillo-Sánchez, Milrad, and Vavoula (2009) to focus on the informal online learning sphere, rather than assume that learning necessarily resides in formal teacher-orchestrated learning activities sited in a conventional classroom setting.

One advantage presented by this three-year study was to check for longer term effects on student academic outcomes as measured by the year-end examinations. As mentioned, the results of the P21C pioneers were analysed not just for 2011 when they were first put on the programme but also in the subsequent years. The Lower Sec pioneers’ results were compared with their cohort in 2012 and 2013 even though by then, the cohort was also involved in the programme. The intent was to see if there was any difference in results of these students who had been on the programme longer than their peers. The results of the Upper Sec pioneers were tracked though their situation was different; they were no longer officially on the P21C programme like their cohort. The study wanted to probe to see if there were any residual effects from the programme.

To recap, the study found a differentiated effect not just at cohort level but also by ability grouping. Firstly, it appears that there was greater effect on student academic results in the Lower Sec. It could be due to the Lower Sec’s greater engagement brought about by the use of the iPad, or the teachers’ less use of the iPad at the Upper Sec, compared to the Lower Sec. As indicated earlier, the pressure of high-stakes examinations at the Upper Sec could have driven teachers to take the more conventional approach to teaching and learning. It was unfortunate as the analysis of the Lower Sec results found significant difference in the low as well as the high ability groups in 2011 and 2012.
Certainly, one needs to interpret these findings very cautiously and the conclusions would benefit from confirmation from replications of the study at other sites and contexts. However, the findings are not unexpected. Fullan and Langworthy (2014) had argued before that technology, when used with sound pedagogy, “unleashes deep learning” (p. 33) which they define as “creating and using new knowledge in the world” (p. 7). In this study, we see evidence of sound pedagogy coupled with the technology that gave the learners the ready access to resource and the opportunity to discuss and clarify their understanding. As such, it is very possible that the access to online resources and community gave the extra help needed by the low ability group and the in-depth exploration for the high ability groups. The fact that there was no longer significant difference by 2013 between the P21C pioneers and their peers could be due to either the peers also reaping the benefits of being on the programme themselves for the second year or the iPad being not as pervasively used in the Upper Sec, due to perhaps pressures of content coverage.

In short, the findings present support for the previous studies that the use of the iPad results in greater learner engagement. The study provides an insight into the differentiated effect it can have on different ability groups. However, one hastens to add that it is not the device per se but how it is used to facilitate the deep learning that educators write about (Angelo, 2012; Fullan & Langworthy, 2014; OECD, 2015). In other words, the technology is not used just as a device for students to find or display information. That would be using technology at a substitution, or at best, augmentation, level with no or little real-functional improvement from having information displayed on hard copy text (Puentedura, 2014). To achieve the desired student outcomes, technology should be used in a transformational way to enable significant task redesign, even tasks previously thought inconceivable. In addition, technology should be used to enable “deep learning tasks characterized by exploration, connectedness and broader, real-world purposes” (Fullan & Langworthy, 2014, p. 7). The teacher’s role changes from focusing on covering content to focusing on developing the students’ ability to take charge of their learning. Indeed, it is when teachers are able to transform their roles and their lessons that we can harness the potential that technology offers in enhancing learning for our Digital Natives.

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Appendix A

Table A. Descriptive statistics for Figure 1

|                      | Engaged learning | Learn more deeply | Learning extends outside class | More collaboration | Recommend P21C2 |
|----------------------|------------------|------------------|-------------------------------|-------------------|-----------------|
|                      | Mean  | SD   | Mean  | SD   | Mean  | SD   | Mean  | SD   | Mean  | SD   |
| Lower Sec            | 3.16  | 1.43 | 3.07  | 1.33 | 3.05  | 1.36 | 3.77  | 1.66 | 3.26  | 1.38 |
| P21C2 (n = 57)       |       |      |       |      |       |      |       |      |       |      |
| Upper Sec            | 2.60  | 1.06 | 2.71  | 1.15 | 3.49  | 1.38 | 3.51  | 1.42 | 2.51  | .95  |
| P21C2 (n = 35)       |       |      |       |      |       |      |       |      |       |      |
Table B. Descriptive statistics for Figure 2

| Year | Engaged learning Mean | Engaged learning SD | Learn more deeply Mean | Learn more deeply SD | Learning extends outside class Mean | Learning extends outside class SD | More collaboration Mean | More collaboration SD | Recommend P21C2 Mean | Recommend P21C2 SD |
|------|------------------------|---------------------|------------------------|----------------------|-------------------------------------|----------------------------------|------------------------|---------------------|-----------------------|--------------------|
| 2011 (n = 92) | 2.95 | 1.33 | 2.93 | 1.26 | 3.22 | 1.38 | 3.67 | 1.44 | 2.98 | 1.28 |
| 2012 (n = 133) | 3.37 | 1.06 | 3.46 | .94 | 3.93 | .93 | 4.03 | 1.03 | 2.98 | 1.30 |
| 2013 (n = 206) | 3.79 | 1.08 | 3.77 | 1.10 | 4.20 | .96 | 4.29 | .91 | 3.45 | 1.30 |

Table C. Descriptive Statistics for Figure 3

| Year | Engaged learning Mean | Engaged learning SD | Learn more deeply Mean | Learn more deeply SD | Learning extends outside class Mean | Learning extends outside class SD | More collaboration Mean | More collaboration SD | Recommend P21C2 Mean | Recommend P21C2 SD |
|------|------------------------|---------------------|------------------------|----------------------|-------------------------------------|----------------------------------|------------------------|---------------------|-----------------------|--------------------|
| 2012 Sec 2 (n = 133) | 3.37 | 1.06 | 3.46 | .94 | 3.93 | .93 | 4.03 | 1.03 | 2.98 | 1.30 |
| 2013 Sec 3 (n = 84) | 3.45 | 1.03 | 3.61 | .94 | 4.13 | .99 | 4.20 | .91 | 3.00 | 1.21 |

Table D. Descriptive statistics for Figure 4

| Year | Engaged learning Mean | Engaged learning SD | Learn more deeply Mean | Learn more deeply SD | Learning extends outside class Mean | Learning extends outside class SD | More collaboration Mean | More collaboration SD | Recommend P21C2 Mean | Recommend P21C2 SD |
|------|------------------------|---------------------|------------------------|----------------------|-------------------------------------|----------------------------------|------------------------|---------------------|-----------------------|--------------------|
| 2012 Sec 2 (n = 133) | 3.37 | 1.06 | 3.46 | .94 | 3.93 | .93 | 4.03 | 1.03 | 2.98 | 1.30 |
| 2013 Sec 2 (n = 122) | 4.02 | 1.03 | 3.88 | .91 | 4.25 | .99 | 4.34 | .94 | 3.75 | 1.21 |

Table E. Descriptive statistics for Figure 5

| Year | Engaged learning Mean | Engaged learning SD | Learn more deeply Mean | Learn more deeply SD | Learning extends outside class Mean | Learning extends outside class SD | More collaboration Mean | More collaboration SD | Recommend P21C2 Mean | Recommend P21C2 SD |
|------|------------------------|---------------------|------------------------|----------------------|-------------------------------------|----------------------------------|------------------------|---------------------|-----------------------|--------------------|
| 2013 Sec 2 (n = 122) | 4.02 | 1.06 | 3.88 | 1.20 | 4.25 | .93 | 4.34 | .88 | 3.75 | 1.28 |
| 2013 Sec 3 (n = 84) | 3.45 | 1.03 | 3.61 | .91 | 4.13 | .99 | 4.20 | .91 | 3.00 | 1.21 |
Table F. Descriptive Statistics for Figure 6

|                  | Engaged Learning | Learn More Deeply | Learning Extends Outside Class | More Collaboration | Recommend P21C2 |
|------------------|-----------------|-------------------|--------------------------------|--------------------|-----------------|
|                  | Mean  | SD    | Mean  | SD    | Mean  | SD    | Mean  | SD    | Mean  | SD    |
| 2011 Sec 3 (n = 35) | 2.60  | 1.06  | 2.71  | 1.15  | 3.49  | 1.38  | 3.51  | 1.42  | 2.51  | .95   |
| 2013 Sec 3 (n = 84) | 3.45  | 1.03  | 3.61  | .91   | 4.13  | .99   | 4.20  | .94   | 3.00  | 1.21  |

Table G. Descriptive statistics for Figure 9

|        | 2011     | 2012     | 2013     |
|--------|----------|----------|----------|
| Mean   | SD       | Mean     | SD       | Mean     | SD       |
| P21C2  | 54.80    | 28.65    | 23.69    | 19.56    | 27.57    | 36.72    |
| Others | 48.63    | 35.34    | 31.26    | 27.29    | 37.75    | 29.99    |

Table H. Descriptive statistics for Figure 10

|        | 2011     | 2012     | 2013     |
|--------|----------|----------|----------|
| Mean   | SD       | Mean     | SD       | Mean     | SD       |
| P21C2  | 15.84    | 23.21    | 38.29    | 38.91    | 41.26    | 39.69    |
| Others | 16.43    | 24.31    | 14.15    | 23.69    | 9.98     | 20.18    |

Table I. Descriptive statistics for Figure 11

|                  | 2011     | 2013     |
|------------------|----------|----------|
| Mean             | SD       | Mean     | SD       |
| Teacher talk     | 53.95    | 32.15    | 28.75    | 41.10    |
| Group discussion | 13.49    | 26.96    | 53.96    | 40.24    |

Table J. Descriptive Statistics for Figure 13

|        | 2011     | 2012     | 2013     |
|--------|----------|----------|----------|
| Mean   | SD       | Mean     | SD       | Mean     | SD       |
| P21C2  | 1.46     | .54      | 1.60     | .66      | 2.06     | .96      |
| Others | 1.88     | .80      | 2.10     | .91      | 2.44     | 1.05     |

Table K. Descriptive statistics for Figure 14

|        | 2011     | 2012     |
|--------|----------|----------|
| Mean   | SD       | Mean     | SD       |
| P21C2  | 1.83     | .58      | 1.94     | .68      |
| Others | 1.94     | .80      | 1.99     | .75      |
Table L. Descriptive statistics for Figure 15

|       | Lower quartile | Median | Upper quartile |
|-------|----------------|--------|---------------|
|       | Mean | SD   | Mean | SD   | Mean | SD |
| 2011      |     |      |      |      |      |    |
| P21C   | 1.85 | .67 | 1.57 | .40 | 1.11 | .23 |
| Others  | 2.56 | .82 | 1.67 | .51 | 1.36 | .43 |
| 2012      |     |      |      |      |      |    |
| P21C   | 2.05 | .86 | 1.67 | .50 | 1.23 | .36 |
| Others  | 2.83 | .93 | 1.85 | .60 | 1.56 | .57 |
| 2013      |     |      |      |      |      |    |
| P21C   | 2.67 | 1.17 | 2.11 | .64 | 1.59 | .78 |
| Others  | 3.18 | 1.11 | 2.21 | .75 | 1.86 | .73 |

Table M. Descriptive statistics for Figure 16

|       | Lower quartile | Median | Upper quartile |
|-------|----------------|--------|---------------|
|       | Mean | SD   | Mean | SD   | Mean | SD |
| 2011      |     |      |      |      |      |    |
| P21C   | 2.15 | .65 | 1.86 | .53 | 1.45 | .34 |
| Others  | 2.42 | .95 | 1.85 | .68 | 1.54 | .55 |
| 2012      |     |      |      |      |      |    |
| P21C   | 2.35 | .73 | 1.93 | .66 | 1.60 | .70 |
| Others  | 2.41 | .81 | 1.96 | .68 | 1.63 | .55 |