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A SNAPSHOT APPROACH OF A SMARTPHONE-ENABLED IMPLEMENTATION

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Smartphones are being adopted en-masse throughout the world. Its adoption in education has witnessed a diversity of implementations with various outcomes. In particular, seamless learning is a broad pedagogical approach key in mobile learning design. With the goals of enhancing academic achievement and self-directed learners, a trial smartphone-enabled implementation was carried out for a unit in the Primary 3 English Language curriculum. The paper will examine the smartphone-enabled implementation with the snapshot approach: from the infrastructure snapshot, advanced infrastructure snapshot, functional snapshot and finally through an example snapshot. These snapshots build on each other and provide a fuller and richer picture of the implementation. The study found that academic achievement and self-directed learning of students was affected with the smartphone-enabled curriculum. Students had higher academic achievement with the smartphone-enabled curriculum compared to the worksheet-based curriculum. However, the results for self-directed learning were more complex. Although the smartphone seems to encourage self-direction, the extent of the learning depends. The example snapshot identifies possible reasons including blind practice and the fostering of word consciousness. Implications and future directions are provided.

Keywords: Mobile learning; methodology; English Language; self-directed learning; education.

1. Introduction

In this increasingly technological driven world, smartphones are being adopted en-masse throughout the world (IDC, 2012), in work and in education (Norris, Hossain, & Soloway, 2011). Smartphones have many features that can be harnessed for teaching and learning (Cochrane & Bateman, 2010). Past research has highlighted how mobile learning can enhance learning outcomes in several ways (Looi et al., 2011; Sandberg, Maris, & de Geus, 2011). Academic achievement has traditionally been the end-goal but in recent years, 21st century competencies have increased in importance (Griffin, McGaw, & Care, 2011). In Singapore, the Ministry of Education (MOE) has developed strategic masterplans by which ICT can be used to enrich the learning landscape (MOE, 2008). One of the key goals in the latest masterplan, the Third Masterplan for ICT in Education (mp3), is to encourage the development of self-directed learners. Self-directed learning is an important competency for the students of today in order for them to gain ownership of learning, monitor their learning and manage new situations they encounter (Fischer & Sugimoto, 2006; Tan, Divaharan, Tan, & Cheah, 2011). Research has also shown that self-directed learning leads to higher academic achievement (Sha, Looi, Chen, Seow, & Wong, 2012; Zimmerman, 1989).

In line with the development of learners' academic achievement and self-directedness, seamless learning has been conceived as a broad pedagogical framework conceived in the context of mobile learning (Chan et al., 2006; Looi et al., 2010; Wong & Looi, 2011). Interacting with technology, teaching and learning (Wong & Looi, 2011), seamless learning removes constraining seams for continuous and sustained learning. With the goal of implementing seamless learning and cultivating self-directed learners, smartphones were adopted in a trial design and implementation of the Primary 3 English Language curriculum at a Primary School in Singapore.

Although smartphones have been in the market for awhile, previous research has examined older students such as those in tertiary institutions (Chen, Teng, Lee, & Kinshuk, 2011; Cochrane, 2010; Hung & Chao, 2012). Also, the pioneers have used it dominantly for out-of-class or informal learning (Sandberg et al., 2011; Wong & Looi, 2010) or for other subjects such as Science (Zhang et al., 2010). There has been limited research examining the use of smartphones for formal learning and for younger students. Moreover, unlike previous studies that focus on the mobilized lesson only (Looi et al., 2009), this study compares the effect of a smartphone-enabled curriculum with a worksheet-based curriculum. The smartphone permits and encourages the learners to 'go deeper and advance their learning', since they have ready access to the various sources of information in the World Wide Web. This platform of learning, by its very mobile and flexible nature, fosters learning from anywhere and anytime, as it is freed from 'the physical confine of classrooms and the rigidity of structured curriculum time'(Ng, 2008). Therefore, this paper asks, what is the effect of the smartphone-enabled implementation on students' academic achievement and self-directed learning?

In addition, to provide broader and deeper understandings of phenomena, many researchers have used mixed methods to analyze the design of implementations (Anderson & Shattuck, 2012; Lajoie, Gauthier, & Lu, 2009; The Design-Based Research Collective, 2003). However, a concern in mixed methods research is that of analytic integration (Yin, 2006). Past research has found a general lack of analytic cohesion in mixed methods studies (Hanson, Creswell, Clark, Petska, & Creswell, 2005). To provide a greater coherence in analysis, we utilize the snapshot approach to organize our study. The snapshot approach, based on snapshot theory (Herbsleb et al., 1995; Murray, 2006), is a lens that enables examinations to be made at particular junctures in a project implementation. These junctions, where the entities are conceptually whole, serve as snapshots for discourse and discussion. We offer the snapshot approach as a viable and systematic approach to analytic integration in mixed methods research. This paper adds on to an earlier work, where only academic achievement was examined (Koh & Looi, 2012). Moreover, we provide a more complete picture of the implementation through the example snapshot.

The paper begins with introducing smartphone-enabled learning, mixed methods research and the snapshot approach. Next, we follow the snapshot approach in its evaluation of an infrastructure snapshot, an advanced infrastructure snapshot, a functional snapshot and finally an example snapshot. An overall discussion and implications is in the penultimate section. The conclusion provides closing remarks, limitations of the study and the future directions.

2. Smartphone-enabled Learning

Many mobile devices are being used for learning. In recent years, smartphones are increasingly adopted for learning. Many of these studies focus on tertiary education (Chen et al., 2011; Cochrane, 2010; Cochrane & Bateman, 2010; Huang, Wu, & Chen, 2012). For instance, Cochrane (2010) examined the use of smartphones and tablets in tertiary education. Using the case study method, the research found that the smartphones enabled a social constructivist pedagogy where students could self-create content, and allow for formative lecturer and peer feedback. In another study, smartphones were complemented by paper-based materials to examine procedural scaffolding (Huang et al., 2012). The research found that students in the procedural scaffolding condition had better learning outcomes (discourse levels, group and individual learning) than the control condition. Students were able to easily access information with the camera on the smartphone using QR codes, reflect and pace their own learning using the scaffolding strategy. This quasi-experiment was complemented by content analysis of the students' discussion.

There have been fewer studies examining younger students using smartphones. One of the pioneers, Sandberg et al. (2011) examined English learning as a second language for 5th grade Dutch students using T-mobile Pulse smartphones. The research performed a quasi-experiment across three conditions: lessons in class, lessons in the zoo with a mobile device, and lessons in the zoo with students allowed to take the device home for a fortnight. The group which took the mobile device home had the highest results. When time was controlled for, there were no differences among the groups. It seems that these smartphones helped to motivate students to use their out-of-class time to learn. Smartphones enabled students to be more self-directed in their learning. Past research on mobile technology has also revealed that smartphones share affordances with other mobile devices that enable learning. For instance, in a case study of 2nd graders using PocketPCs, Looi et al. (2009) found that the affordances of supporting multiple entry points, multi-modality, student improvisation and creation and sharing of artifacts on the move, helped personalize learning and encourage student self-direction.

Past studies have enabled us to gain various understandings of how smartphones affect academic achievement and self-directed learning. However, the relationship between smartphone affordances, the use of smartphones, and learning outcomes is not always clear. Past studies have typically used a single method to show a certain aspect of the smartphone such as a case study to examine the features of the smartphone (Looi et al., 2009) or a quasi-experiment for the learning outcome of academic learning (Sandberg et al., 2011). To enable a deeper and broader understanding of smartphone-enabled learning, we employ mixed methods research.

2.1. *Mixed methods research*

Mixed methods research is defined as a type of research which “combines elements of qualitative and quantitative research approaches (e.g. use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration”(Johnson, Onwuegbuzie, & Turner, 2007, p. 123). This method generally includes the collection of numbers and words, “where neither type of method is inherently linked to any particular inquiry paradigm” (Greene, Caracelli, & Graham, 1989, p. 256). Many researchers have used mixed methods in design-based research as well as other implementation evaluations (Anderson & Shattuck, 2012; Lajoie et al., 2009; The Design-Based Research Collective, 2003). However, analysis in mixed methods research has been an issue since its advent. As Yin (2006) suggests, the unit of analysis holds a study together. However, in mixed methods studies, “different methods inherently favor different units of analysis—leading to another threat to the integrity of a single study” (Yin, 2006, p.43). Analytic integration, an essential component in mixed methods studies, is not uncomplicated, as each methodology (i.e. quantitative and qualitative) comes with its “own preferred and distinct analytic techniques” (Yin, 2006, p.45).

This was corroborated by Hanson et al. (2005) when they studied 22 mixed methods studies published between 1986 and 2000. Their purpose was to provide an overview of mixed methods research designs, since they found a general absence of such discussions. They found the following: ten of the studies (45%) analyzed the quantitative and qualitative data separately; seven of the studies (32%) were connected without transformation during data analysis; three studies (14%) separated and then transformed the qualitative data into quantitative scores; two studies (9%) were connected and transformed. Their study revealed a general lack of analytic integration in many mixed methods studies. In the same manner, Greene et al. (1989) examined 57 articles and found only five studies which had “achieved such integration” (p.270) of both the quantitative and qualitative data.

The lack of integration was similarly found by Bryman (2006) in his extensive review of 232 mixed methods research articles in the period of 1994 to 2003. He found only 18% of the articles had genuinely integrated both the quantitative and qualitative data. This lack of integration suggests that “mixed methods researchers may not always be making the most of the data they collect” (Bryman, 2007, p. 9). This demonstrates the difficulty of the issue of integrating or data mixing, i.e. explicitly relating both sets of quantitative and qualitative data (Kettles, Creswell, & Zhang, 2011).

In the smartphone learning literature, there have been limited studies using mixed methods (Huang et al., 2012; Ng & Nicholas, 2012). One example is the study by Huang et al. (2012) that used mixed methods for the data analysis. This study had a quasi-experimental design with a pre-test and post-test. The research also audio-recorded group discussions and performed content analysis on the transcripts. While the study contributes to a greater understanding of student discourse, it does not clearly integrate the outcomes with the smartphone implementation or its features.

To provide a full picture of the smartphone implementation and to ameliorate the difficulty of integrating the data sets, this study has taken a systematic approach to analyzing our phenomenon – the snapshot approach.

2.2. *Snapshot approach*

In this study, the snapshot approach is adapted as a frame of analysis for the smartphone implementation in the English Language curriculum in a Primary School. The snapshot approach is derived from snapshot theory which focuses on snapshots as building blocks to explain system design (Murray, 2006). The snapshot theory is originally derived from the Computer Science discipline whereby software programmers use snapshots at critical junctions to generate discourse in a software development (Herbsleb et al., 1995). Entities in a snapshot must be conceptually whole in order to provide a frame for discussion. This research borrows key concepts in snapshot theory and utilizes it as a framework to analyze the relationships in a smartphone implementation. Snapshot theory proposes that explaining a phenomenon requires a series of snapshots that have particular characteristics and relationships. These snapshots typically start with an infrastructure snapshot (main features of the tool), followed by an advanced infrastructure snapshot (further knowledge of the infrastructure composition, enriching the older snapshot), a functional snapshot (how the tool functions with the features of the tool), and an example snapshot (how the tool works). Snapshots can be weak or complete. A weak snapshot denotes incomplete insight while a complete snapshot encompasses all details to explain the phenomenon.

In the same way that the snapshot analysis provides a useful frame of analysis for computer software implementations (Herbsleb et al., 1995), these snapshots also provide an integrative framework for our implementation. Each snapshot serves as a critical discourse in which to examine the specific component of the implementation. The snapshot can serve as the building block for the next snapshot. Alternatively, the snapshot can provide feedback for the previous snapshot and inform the design and implementation. Figure 1 below illustrates the process.

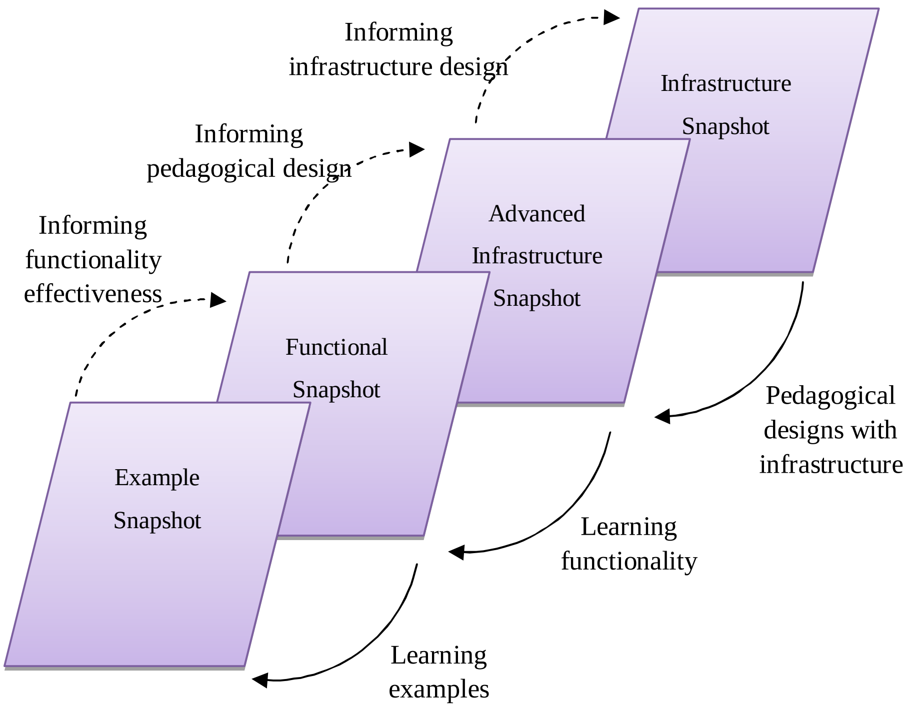

Figure 1. Snapshot approach.

Starting from the infrastructure snapshot, we examine the affordances of the tool. Next, pedagogical designs are built from the infrastructure to form the advanced infrastructure snapshot. Basically, what are the uses of the features of the tool. The advanced infrastructure snapshot is then a building block for the evaluation of learning functionality. When the effectiveness of learning is evaluated, the example snapshot is built on top of it, which provides illustrations of students' use of the tool. This adds to a richer picture of the phenomena.

In the reverse manner, the example snapshot informs functionality effectiveness, where specific examples of learning can be seen. The functional snapshot informs the pedagogical design, as the learning outcomes help decides if certain instructional strategies should be revised. Lastly, the advanced infrastructure snapshot informs infrastructure design, calling to question features of the tool that can be improved.

The snapshot analysis offers a systematic way of organizing mixed methods research.

Through using these snapshots the link between methods is shown, thereby providing analytic integration. This integration shows an analytic process from the technology features to the usage, effectiveness and user feedback. This enables a rich and fuller picture of the whole phenomenon to be seen.

We proceed to flesh out the snapshot approach in the following section.

3. Snapshot Analysis

This snapshot analysis begins with the infrastructure snapshot, followed by the advanced infrastructure snapshot, the functional snapshot and the example snapshot. Our phenomenon is the implementation of the smartphone-enabled curriculum. The entities include the smartphone features, curriculum design and activities, the students' performance, and student artifacts. Each snapshot is a juncture for discussion. Hence, each snapshot will include the contents of the snapshot (the entities) and related findings.

In our paper, we have used quantitative methods mainly in the functional snapshot and qualitative methods in the advanced infrastructure snapshot and the example snapshot. Quantitative data was collected from performance tests, data logs from the system, and surveys while qualitative data was collected from open responses on a survey, student artifacts, and observations.

3.1. *Infrastructure snapshot: Smartphone features*

We begin by analyzing the infrastructure of the smartphone, that is, the features or affordances of the tool. The Nokia Lumia 710 was used. Here is a list of the main features of the smartphone:

- Platform: Windows Phone 7.5
- Form factor: lightweight
- Image capture: back-facing camera
- Internet connectivity: via 3G and Wi-Fi
- Touch screen
- Voice: recorder
- Video: recording and streaming
- Applications: Among other applications available in the (phone itself and) Windows marketplace, the project had a specially designed a suite of software termed myDesk with three main applications
  - Map-It: mind-mapping application
  - Sketchbook: a drawing tool
  - Blurb: structured note-writer
  - This suite of software was supported by a myDesk learning management system for teachers to view, manage and grade students work

Figure 2. Smartphone with menu of myDesk.

These features enable seamless learning to take place (Chan et al., 2006; Looi et al., 2011). Seamless learning is a broad pedagogy that interacts with technology, teaching and learning (Wong & Looi, 2011). Its chief tenant is that learning is a continuous process across formal and informal learning environments (Looi et al., 2010). The above-mentioned smartphone features enable the smartphone to be used in a self-directed manner by students 1) across time, 2) across locations, and in 3) multiple modes (audio, text, image, and video). The smartphone could be used at any time by the student. It had 24/7 Internet connectivity and students could access websites at their convenience. The smartphone was also lightweight and could be brought about with the student anywhere. Lastly, the smartphone affords multiple modes of information transmission namely audio, text, image and video. Students could record their voices, type messages, take pictures and film videos on their smartphone. Similarly, students could listen to audio files, read messages, view pictures and videos easily on their smartphones. Figure 2 is a picture of the smartphone.

3.2. *Advanced infrastructure snapshot: Smartphone usage for English*

With an understanding of the infrastructure of the smartphone, we now examine how the smartphone was used in English Language learning.

A pedagogical choice of the project was that each student would have a smartphone, for the whole school year. This is also known as a 1:1 computing design. Students (and their parents) would be responsible for the device. For the English Language curriculum, the project team decided to mobilize a unit of the existing English curriculum. Seamless learning and self-directed learning were the two main pedagogical goals. In terms of English Language content, the teachers focused the mobilized curriculum on vocabulary development, identification of noun and verb, tenses, metaphors, and antonyms. Instructional activities were designed to help students gain content knowledge and self-directedness through using the smartphones. These activities cumulated into 9 possible assignments for students which are elaborated below.

Vocabulary: The unit started with the teacher reading a story which had mystery as the theme. Students created a mind map of the story using the application "Map-It" on the smartphone (Assignment 1). This encouraged them to remember the new vocabulary they had learnt. In addition, students used the dictionary application to search for the meaning of new words. Students seamlessly switched between the learning tasks, from the storytelling activity, to entering the English terms to searching for information due to the availability of the smartphone and its applications. An assignment termed "Word Groups" (Assignment 4) was created where students identified verbs that were associated with spying and those not associated with it. This encouraged students to exhibit understanding of vocabulary words through allowing them to classify the words. Using "Map-It" students could easily classify the verbs. Students also used the audio recorder to record themselves reading a passage (Assignment 8). Teachers encouraged students to audio record themselves and to search for the word meanings at home, encouraging self-directed learning and informal learning.

Identification of noun and verb: Using the application "Blurb", students were given words such as "spy" and tasked to write sentences using the word as both a noun and a verb (Assignment 3 and 9). This task engenders an identification and an understanding of word class, before the possibility of proceeding with the construction of the sentences. Students were tasked to write a few sentences in class and to write a few more sentences after the class, at their own time. Students were also challenged to come out with these kinds of words, and write a sentence. This learning activity emphasizes seamless learning encompassing formal and informal environments.

Tenses: Students helped each other to take a photo of each other using the camera function and then used "Sketchbook" to create a disguise (Assignment 2). Students learnt about tenses as they recounted what they did in "Sketchbook". For instance, after drawing curly blue hair on her image, the student wrote, "I drew a wig on my hair". While this activity was dominantly about personalized learning, to a certain extent it had an element of social learning as students had to cooperate in taking the picture.

Metaphors: For the activity on similes, students either took a picture or drew an image of the simile and annotated it e.g. as busy as a bee (Assignment 6 and 7). Once again, teachers encouraged students to do this activity out of class. Several students took pictures of ants and flowers from the school garden or at home. Others took pictures of animals like pigs or bees from objects at home. This activity encouraged seamless learning in formal and informal contexts.

Antonyms: Using "Map-It", students identified and classified positive and negative antonyms (Assignment 5). Students started the activity in class and were encouraged to continue it after school hours, allowing formal and informal learning.

3.3. *Functional snapshot: Implementation effectiveness*

The functional snapshot next provides an evaluation of the utility of the earlier snapshot. The effectiveness of the smartphone-enabled implementation is examined in two areas: student academic achievement and the relationship between self-directed learning and academic achievement.

3.3.1. *Academic achievement*

A 30-mark English assessment was developed to measure the academic achievement of students. This was administered to the experimental group as well as a control group. The test had 5 sections covering the following: Vocabulary (S1), Identification of noun and verb (S2), Tenses (S3), Metaphors (S4), and Antonyms (S5).

The experimental condition consisted of 114 students (3 classes) while the control had 68 students (two classes). In the control group, students were taught the same content using the existing teaching method which is predominantly worksheet-based. The mean score for the post-test for the smartphone-enabled group was higher at 25.88 compared to the mean score of the control group, 21.25. A Welch's t-test was performed between the experimental classes and the control classes. The test showed that the mean scores were significantly different at $p<.001$. This suggests that the smartphone-enabled curriculum intervention helps students in their academic achievement.

A sectional analysis was also conducted. Students in the experimental group had higher means for all sections compared to the control. All sections were significantly different except for section 4, the section on metaphors. This suggests that metaphors are a challenge for Primary 3 pupils to understand. Indeed, during one of the weekly teachers meetings, the teachers agreed how it was conceptually difficult and explained that this is the first time students were taught this. Nevertheless, the smartphone-enabled curriculum compared to the non-smartphone-enabled curriculum enabled the students to improve on the other aspects of academic achievement.

Reliability and validity are two key concerns in experimental research. To address reliability, students in both conditions received the same test treatment. The same amount of time was allocated to students, 30 minutes, and students performed the test in their classroom. Also, the test was designed by the curriculum designer and the Level Head of the English Language Department who did not personally teach any of the students, and according to the learning outcomes of the unit.

To address validity concerns, we performed class comparisons as the students' were in classes based on the school's practice of ability grouping. For the classes using the smartphone-enabled curriculum, class X was regarded as high ability, class Y as mixed ability, and class Z as lower ability. For the control classes, class W was considered a higher ability class while V a lower ability class. Thus, it was not possible to randomly assign students into experimental and control groups. Results then may have been skewed due to one of the control classes being of a much lower ability.

We compared class X and W, and Y and W using one-way ANOVA. The second test, in particular is interesting, as class Y, was a mixed ability class, and was considered lower in ability than class W, a control class.

For class X and W, the average total score for X was 27.61 while class W was 25.86. Students from class X performed significantly better in vocabulary (S1), antonym learning (S5) and on the whole. There were no significant differences for noun and verb (S2), tenses (S3) and metaphor (S4). Also, class X students scored higher than W for all sections except for S2. For the second test, the average total score for class Y was 25.84 which is very close to W, 0.02 marks lower. There were no significant differences between the total scores of the two classes. However, sectional comparison showed significant differences. The smartphone-enabled class had significantly higher scores in vocabulary (S1) and antonym learning (S5). On the other hand, the control class had significantly higher scores than the smartphone-enabled class in the identification of noun and verb (S2) and tenses (S3). There was no significant difference for scores in section 4 on metaphors. The results are tabulated in Table 1.

Based on these results, the smartphone-enabled curriculum seems to help the mixed ability students attain scores on par to their higher ability peers. However, in terms of emphasis, the smartphone-enabled curriculum resulted in higher vocabulary and antonym learning as compared to the identification of differences between nouns or verbs, or understanding tenses. This suggests that the smartphone-enabled curriculum helps to build content knowledge more than the application of that knowledge.

Moreover, for the experimental group, a pre-test and a post-test was carried out to measure students gain in academic achievement. Students on average scored 22.69 for the pre-test and 25.88 for the post-test. There is a mean difference of 3.18 between the two tests. A paired samples t-test showed a significant difference of $p<.001$ between the two tests. This indicates that the smartphone-enabled curriculum improves the academic achievement gain of students.

A sectional analysis was performed and there were significantly higher scores for section 1, 3, and 5 (vocabulary, tenses, and antonyms). In fact, the most improvements were in vocabulary and tenses. However, there was no significant improvement in sections 2 and 4 (identification of noun and verb, and metaphors). The results are shown in Table 2. A possible implication derived from the results is that identifying nouns and

Table 1. Post-test scores of classes W and Y.

	Class W (Control)				Class Y (Experimental)				ANOVA results
n = 43	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.	
S1	2	5	3.77	1.00	2	5	4.30	.77	F = 7.74, p =.007
S2	2	5	4.72	.63	0	5	4.12	1.47	F = 6.17, p =.015
S3	8	10	9.70	.51	7	10	9.37	.82	F = 4.89, p =.030
S4	3	5	4.58	.55	3	5	4.37	.73	F = 2.29, p =.134
S5	0	5	3.09	1.07	0	5	3.60	.93	F = 5.63, p =.020
Total Score	21	29	25.86	1.83	15	30	25.84	2.89	F = .002, p =.965

Table 2. Paired samples test of experimental group.

n=114	Pre-test				Post-test					
	Min	Max	Mean	S.D.	Min	Max	Mean	S.D.	t	Sig.
S1	0	5	2.92	1.33	0	5	4.12	1.06	-9.44	.000
S2	0	5	4.04	1.24	0	5	4.20	1.22	-1.14	.258
S3	0	10	8.31	1.61	6	10	9.45	.86	-8.70	.000
S4	0	5	4.20	1.03	2	5	4.32	.83	-.93	.353
S5	0	5	3.11	1.18	0	5	3.69	.99	-5.64	.000
Total Score	0	30	22.69	4.11	14	30	25.88	3.22	-11.33	.000

verbs and metaphors are difficult for Primary 3 students to grasp. The smartphone-enabled curriculum seems to help students gain more vocabulary content but students may not know how to use these words correctly.

The data was compared across the three classes and slight differences were found. For class X, there was a significant improvement for vocabulary and tenses but not much improvement for identifying noun and verbs, metaphors and antonyms. Class Y had the most improvement, demonstrating significant increases for sections 1, 3, and 5. Class Z showed significant improvement for the understanding of tenses and antonyms but no significant increase for vocabulary. There was also a decline in scores for sections 2 and 4.

These differences in results across classes could be due to the student ability levels and their prior knowledge. For instance, high ability students already have a good grasp of English content and so did not learn much more for antonyms during the lessons. Mixed ability students who may not have much prior knowledge were able to gain the most from the smartphone-enabled curriculum as seen by the higher number of sections that improvement was shown. For class Z, the lack of prior knowledge could have affected their results.

Another possible reason could be how the teachers taught the unit. Teachers gave different amounts of challenges and tasks to students. For instance, Class X was given 5 words to write sentences in nouns and verbs. For Class Y it was 3 and in Class Z, students chose one word only. Given a similar amount of time (i.e. class teaching periods), teachers could not enact the smartphone-enabled curriculum in the same way, as they needed to cater to the learning abilities and pace of the students in their classes. It could be that given more time and opportunity to attempt more learning tasks, class Z could achieve comparable results as the other classes. Nevertheless, the mixed results for class Z suggests that differentiated strategies for lower ability students are needed, especially for students to grasp difficult concepts such as metaphors.

3.3.2. *Self-directed learning and academic achievement*

As aforementioned, the smartphone-enabled curriculum intends to enhance students' self-directed learning. Past research has shown a link between self-directed learning and academic achievement (Stipek, Newton, & Chudgar, 2010; Zimmerman, 1989). For instance, Stipek et al. (2010) found that self-directed learning behavior such as working independently and accepting responsibility for a given task, led to higher literacy scores in primary school students. Self-directed learning may be measured in several ways such as behavior observation, survey feedback and proxy measures (Tan et al., 2011). In particular, proxy measures are an unobtrusive method of measuring students' independent learning (Sha et al., 2012). Using number of submissions as a proxy for self-directed learning, we evaluate the hypothesis that the higher number of submissions will lead to an increase in academic achievement.

We obtained the data for the number of assignment submissions from the myDesk learning management system. For this trial unit, there were a total of 9 possible assignment submissions. Average submissions per student in the smartphone-enabled group were 6.22 while the median was 6. We found that number of submissions was significantly correlated with post-test scores at r=.196, p=.036 (2-tailed). The number of assignment submissions was also significantly correlated with section 1 (vocabulary), r=.189, p=.043.

Using a path analysis model, the relationship between number of submissions and academic achievement was non-significant (b=.227, p=.069). A multi-group path analysis was also done to compare all three smartphone-enabled classes. For Class X, while there was a positive path, b=.043, this was non-significant at p=.697. For Class Y, a positive and significant relationship was found (b=.381, p=.040). For Class Z, the relationship between submissions and academic achievement was estimated at b=.198, p=.621. There was no significant relationship between submissions and academic achievement for Class X or Z except for Class Y.

This suggests that self-directed learning does lead to academic achievement but only under certain conditions. The results seem to suggest that self-directed learning can affect academic performance for the mixed ability students but not for the lower or higher ability students. For the higher-ability students, there could be a ceiling effect as students all scored relatively well already. For Class Z, the weaker ability class, it could be that the assignment and learning activities designed were above their current level of comprehension. Thus, these submissions of assignments were unable to capture the quality of their learning. Possibly, the assignments need to be differentiated for the lower ability students and these were not differentiated enough to meet their learning needs. Nevertheless, the example snapshot could shed more light on the reasons.

3.4. *Example snapshot: A look at the students*

In the example snapshot, we examine "how it works". In other words, *how* did the smartphone affect students' learning? We elaborate on student examples to give a fuller picture of the smartphone's role in English Language learning. Data for this section is drawn from artifacts that these students had submitted on the system as well as an end-of-year survey. An open-ended student survey was administered to the students at the end of the year. Based on the data, we grouped the findings into five themes. We shall first describe the details of the selection criteria and the specific details of the students

Table 3. Descriptive statistics of the mean difference in post-test and pre-test scores.

N	Valid	113
	Missing	1
Mean		3.004
Median		3.000
Std. Deviation		2.747
Range		14.5
Minimum		-5.5
Maximum		9.0

selected, before we outline the main findings from each theme. The five themes are self-directed word consciousness, variations in smartphone learning engagement, smartphone as instrument for out-of-class learning, alignment of smartphone features with child's development, and self-directed learning is doing with understanding.

3.4.1. *Student selection*

We selected students based on their differences in marks between the post-test and the pre-test. Tables 3 and 4 report the descriptive statistics of the mean difference between

Table 4. Frequency of mean difference scores.

		Frequency	Percent
Valid	-5.5	1	.9
	-3.0	1	.9
	-1.5	1	.9
	-1.0	5	4.4
	-.5	3	2.6
	.0	7	6.1
	.5	6	5.3
	1.0	11	9.6
	1.5	4	3.5
	2.0	8	7.0
	2.5	9	7.9
	3.0	7	6.1
	3.5	6	5.3
	4.0	2	1.8
	4.5	11	9.6
	5.0	7	6.1
	5.5	8	7.0
	6.0	3	2.6
	6.5	2	1.8
	7.0	1	.9
	7.5	3	2.6
	8.0	3	2.6
	8.5	3	2.6
	9.0	1	.9
	Total	113	99.1
Missing		1	.9
Total		114	100.0

post-test and pre-test and the frequencies respectively. Based on this list we identified students with the highest mean difference and students with the lowest mean difference for maximum sampling variation. This resulted in the selection of 7 students where there was a clear mark demarcation. Four students had the highest mean differences (8.5 to 9 marks) and three students had the lowest mean differences (-5 to -1.5).

3.4.2. *Student details*

The seven students have been given pseudonyms as shown in Table 5. This table also reports student's mean difference scores, as well as the difference for each section, post-test score and the total number of submissions.

Among these students, Alice from Class Z had the highest gain in improvement. Looking at the number of submissions, this student had submitted the most number of assignments among these students. Although not statistically significant, it does give hope that among the lower ability pupils, the higher number of submissions does demonstrate a certain degree of self-directed learning and better academic achievement. Still, it demonstrates the need to look at the quality of student submissions.

Ben, Cally and Debbie had a mean difference of 8.5 each. Their improvement in scores was mainly in the sections vocabulary (S1), identification of noun and verb (S2), and tenses (S3). Interestingly, they had varying amounts of submissions. In particular, Cally had a higher number of submissions, 6 out of 9. She also improved in all areas of the test, from S1 to S5 by at least one point.

Edwin, Fred and Ginny were the three students with the lowest mean difference in scores. Their pre and post scores showed that not only was there no improvement, their post-test scores were actually lower than the pre-test scores. The differences ranged from -1.5 to -5.5. All students suffered a one-point drop in the section on metaphors. The last two students, Fred and Ginny expressed negative attitudes towards the use of smartphones for learning. Two out of the three students had low submission rates (Edwin & Ginny). Fred though had a higher submission rate, 6 out of 9, but scored lower in his post-test.

Table 5. Mean difference scores of selected students.

Student	Class	Difference between Post-test and Pre-test scores						Post-test Score	Number of Submissions
		Mean	S1	S2	S3	S4	S5		
Alice	Z	9	2.5	2.5	2	0	2	27	7
Ben	Y	8.5	2.5	2	2	0	2	26	2
Cally	Y	8.5	3	1.5	1	2	1	29	6
Debbie	X	8.5	3	3.5	2	0	0	26	3
Edwin	Z	-1.5	-2.5	1	2	-1	-1	20.5	3
Fred	Z	-3	-1	-1	-1	-1	1	24	6
Ginny	Y	-5.5	0	-3.5	-1	-1	0	15	3

3.4.3. *Theme 1: Self-directed word consciousness*

All students except Ginny submitted the story map assignment (Assignment 1). This assignment was on "Map-It" and students were guided to write sentences with keywords in text boxes such as the problem, the main character, the clue and the solution. We observed that the first four students (Alice to Debbie) were able to write full sentences in the text box. These were mostly grammatically correct too. Students took note of their tenses. They also incorporated the vocabulary words they learnt through the story read in class such as "jiggled". Moreover, while this was started in class, students continued the sentences out-of-class. Much effort can be seen on the part of this group of students. On the other hand for Edwin and Fred, many sentences were incomplete. It suggests that these students had trouble forming sentences. It seems that for this particular assignment, the earlier group of students was more self-directed than Edwin and Fred.

The students with the higher mean differences also submitted the word group assignment unlike the other group. This assignment required the students to sort the words which they brainstormed in class into two categories provided by the teacher (i.e. closed sorting). This activity required an understanding of the individual words, and how they relate to each other and to the categories provided, before they can be correctly sorted. These multiple exposures to and manipulation of the words in class and at home are beneficial for a long term understanding and retention of the vocabulary (Lawrence, 2009; McKeown, Beck, Omanson, & Pople, 1985; Nagy, Herman, & Anderson, 1985). Figure 3 shows the closed sorting Debbie has done.

In all, these smartphone activities foster word consciousness which is one of the key components of an effective vocabulary instruction program (Graves, 2006), where word consciousness involves "being aware and interested in words and word meanings and noticing when and how new words are used" (Lane & Allen, 2010, p. 365). The smartphone provides a platform for the students to explore the vocabulary words at their

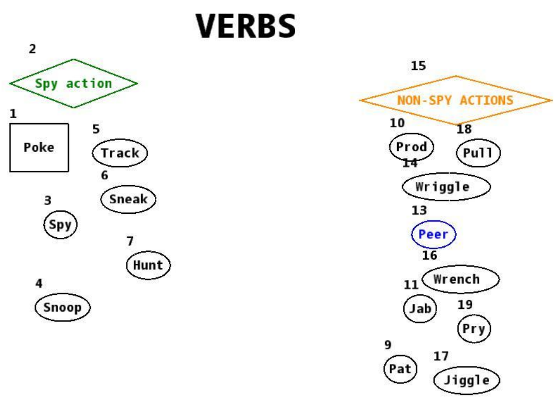

Figure 3. Word group sorting by student Debbie.

own time. Moreover, these repeated encounters with words facilitate a long term memory and understanding of new words (Beck, McKeown, & Kucan, 2008). These examples highlight how the smartphone curriculum helped students who were self-directed, to learn, especially in the area of vocabulary. Students' activity on the smartphone applications allows them to be more aware and conscious of the use of the words. This provides an advantage over the traditional pedagogical practice.

3.4.4. *Theme 2: Variations in smartphone learning engagement*

Some students were more engaged in using the smartphone to learn compared to other students. This seemed to be the case for Debbie and Ben. To the survey question on why students liked their English lessons, Debbie responded that "We get to use phones and do assignments. It is fun." This highlights the motivating factor that smartphones have for students in helping them learn English. Ben was similarly engaged. For the story mapping assignment, Ben even spent time to give each textbox a unique color (Figure 4). This highlights the enthusiasm and motivation the students have for using the smartphone for learning which could translate to them retaining English vocabulary.

However, as seen by the lack of submissions of certain students, the smartphone did not always motivate them in their learning. Students reported on other more attractive uses of the smartphone, predominantly, the viewing of movies for leisure. A few students even fooled around with the assignments. Submissions by Ginny did not follow the teacher's instructions. For example, assignment 3 on identification of noun and verb, the student did not write 2 different sentences of the word as required. These students seem to be easily distracted by the entertainment features of the smartphone. Trying to engage these students to learn with the smartphone is a challenge.

3.4.5. *Theme 3: Smartphone as instrument for out-of-class learning*

The smartphone enabled self-directedness out-of-class. An example is seen in Cally who was very active in working on her simile task. She used the phone to take pictures of the environment around her outside of class. Using "Sketchbook", she annotated the appropriate simile on the picture. In total, the student submitted four different pictures all with appropriate annotations. An example is shown in Figure 5. As seen in the improvement in the post-test, Cally gained in her performance in the section on

Figure 4. Story map example from student Ben.

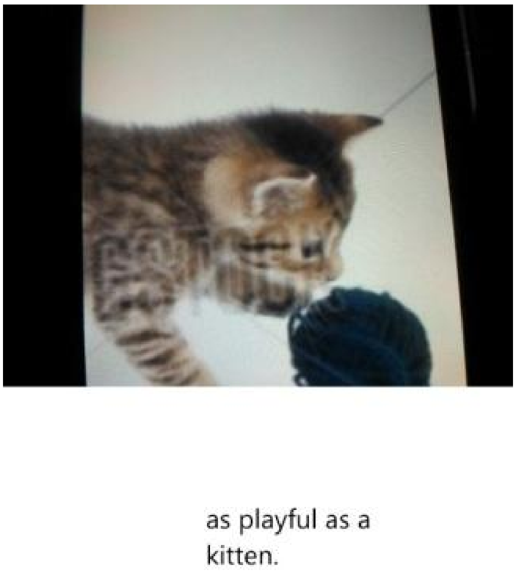

Figure 5. Simile example.

metaphors.

To the survey question, “what do you use your smartphone for?”, 6 out of the 7 students specifically referred to using the smartphone for “homework” and “assignments”. This was especially so for Alice, Ben, Cally and Debbie. For example, Alice shared about how the phone was used “to search and do my homework”. It suggests that the smartphone enabled them to be self-directed and want to work on their learning in non-school contexts.

3.4.6. *Theme 4: Alignment of smartphone features with child’s development*

In the end-of-year survey, interestingly, students who had higher mean differences (most improvement) all reported liking the smartphone. Fred and Ginny, who had lower mean differences (no gain in their marks), disliked using the smartphones. Fred highlighted how the smartphone was “hard to write” while Ginny focused on how it “increases my myopia”. Even though the trial unit was in the middle of the year, these difficulties for the child continued to persist until the end of the year. As the implementation of Unit 6 was done in Term 2 (first half of the school year), many of the children were just 8 years of age. Possibly, the stages of the child’s development, in this case, the psychomotor development of the students need to be taken into consideration, especially so when it comes to the use of smartphone technology – a new learning tool. Difficulties with using the smartphone for typing could also be related to students’ learning styles. For Class Z students, all of them were very responsive to Assignment 8, which required them to record their voices reading a story. This suggests offering multiple modes of learning activities to cater to students' learning development.

3.4.7. *Theme 5: Self-directed learning is doing with understanding*

Self-directed learning requires students to have some understanding of what they are doing in order for them to learn. Otherwise, "doing" without "understanding" is like pure blind practice. Fred was one of the students who actively submitted his assignments, submitting 6 out of the 9 assignments. However, he turned out to be one of the students who did not exhibit any gain in the post-test. When examining his artifacts, we found instances of misconceptions, such as the inability to differentiate nouns from verbs. Fred wrote sentences that repeated the same usage of the word e.g. "Crack as a noun: I use a hammer to crack the wall. Crack as a verb: The police have to crack this case." In this case, Fred's self-directed actions continually reinforced his wrong concepts. This suggests that self-directedness may need to be scaffolded, or else it might lead to blind practice and "doing" without "understanding". This seems to be especially so for students in the lower ability class. This finding also explains why in the functional snapshot, the overall relationship between the number of submissions and academic achievement was not significant.

4. Overall Discussion and Implications

In this paper, we used the snapshot approach to analyze our research question. We first examined the features of the smartphone in the infrastructure snapshot. Next, the advanced infrastructure snapshot revealed how the smartphone features and its use enabled academic achievement and self-directed learning. In the functional snapshot, we demonstrate how the affordances and usage enabled the effectiveness of the smartphone in terms of our research goals. Lastly, the example snapshot illustrates the features, use and functionality in action and provides deeper insights related to academic achievement and self-directed learning. In the following sub-sections, we discuss the outcomes of academic achievement and self-directed learning and provide implications for educators, designers and researchers.

4.1. *Academic achievement*

Learning English Language with the smartphone can enable students to improve academically. The functional snapshot provides some statistical support while the example snapshot reveals that the smartphone curriculum was particularly strong in vocabulary instruction. In the literature, vocabulary is considered one of the best predictors of general reading performance and school achievement (Beck, McKeown, & Kucan, 2002; Beck et al., 2008). The more words a student knows, the better equipped the student is with regard to decoding and accessing the written print (Blachowicz, Fisher, Ogle, & Watts-Taffe, 2006). Past research has shown that there is a wide disparity in terms of the vocabulary development among the students entering the education system

(Elleman, Lindo, Morphy, & Compton, 2009). As such, it is crucial that effective vocabulary instruction should be one of the key focuses for literacy teachers. According to Beck et al. (2008), for vocabulary instruction to be effective and increase reading comprehension, there should be: multiple exposures to words taught; explicit definitions of words; introduction to and coverage of the various contexts that the words occur in; and deep processing of the words. The smartphone curriculum utilizes these aspects of vocabulary instruction through its learning applications, such as “Map-It”. For instance, this application was used in two ways – as a story mapping tool and as a word sorting tool.

Despite the smartphone-enabled curriculum, our findings reveal that some students were more word conscious than others. Also, the experimental group seemed to be less able to apply the words that have learnt into context. Multiple exposures to words, albeit important, are not enough for effective vocabulary development. The students must have opportunities to make relevant connections with their background knowledge and prior experiences (Armbruster, Lehr, Osborn, & Adler, 2001). For this to be done, teachers must facilitate this during class time, before the students engage with out-of-classroom activities. Also, an effective vocabulary program needs to include two other aspects: 1) providing rich and varied language experiences and 2) teaching word-learning strategies. This seems missing from the smartphone-enabled curriculum and could explain why certain experimental and control group differences were non-significant. These should be incorporated into the curriculum.

The example snapshot also suggests that developmental issues could arise when students use the smartphones. One possible solution is to utilize the smartphone’s function of multi-modalities. For those students who find writing sentences on the smartphone a difficulty, audio and video recording functions should also be made available. However, there is a limit to this as English language learning is also about writing skills which should be cultivated in paper and digital forms. Still, we believe that these multiple modalities could help the student reduce their cognitive load and increase their recall as suggested in other studies (e.g. Joseph & Uther, 2009).

4.2. *Self-directed learning*

Past research has emphasized that technology such as mobile devices help encourage self-directed learning (Fischer & Sugimoto, 2006; Sha et al., 2012). This study is no different. We found that generally, students were enthusiastic to use the smartphones for learning. Students were willing to use the smartphone out-of-class, at their own time, to do their assignments. Although this form of self-direction is still very much guided by a teacher, we see forms of student ownership and responsibility for their own learning. With the help of the smartphones, students took charge of their own learning.

Yet, self-directed students could be caught in blind practice or non-learning activities as revealed in the example snapshot. This echoes past research that encourages students to actively reflect on their own learning to reduce blind practice (Brown, 2004). On one hand, it does imply that technology does not replace the teacher; the smartphone’s role was to enhance the learning but the teacher plays an important role in providing feedback for students' self-directed learning. For students who were self-directed in other ways, it also suggests that activities need to be designed to further engage the students and help them to be self-directed in a meaningful way. As suggested earlier, the smartphone-enabled curriculum could be designed to make greater connections with authentic tasks and prior knowledge. The activities also need to consider students' learning abilities and be differentiated to provide more scaffolds and feedback for the lower ability pupils.

On the other hand, technology could be designed to be a better scaffold for students' self-directed learning. This can be done at the learning management system level for instance, by designing the system such that it is easy for teachers to view all students' submissions and give just-in-time feedback. Other scaffolds require the use of artificial intelligence to provide automated feedback and help students' self-directed learning (El-Bishouty, Ogata, Ayala, & Yano, 2010).

This study also provides some evidence of the positive relationship between self-directed learning and academic achievement. In this analysis, we used the quantitative proxy, number of submissions as a measure of self-directed learning. However, our analysis reveals that quality of submissions is also important to help us understand self-directed learning. Both quantity and quality are needed to measure self-directed learning. To that regard a survey specifically on self-directed learning is designed which will be complemented by student focus groups. Further research on self-directed learning must be done.

5. Conclusion

Using the smartphone, students can easily share their own understandings without the fear of time constraints within the allocated classroom time. Learning becomes seamless. The smartphone-enabled curriculum was suggested to affect academic achievement and self-directed learning. Our findings show some support for the effectiveness of smartphones on academic achievement. Students had higher total scores with the smartphone-enabled curriculum compared to the worksheet-based curriculum. However, the results for self-directed learning were more complex. Although the smartphone seems to encourage self-direction, the extent of the learning depends. The example snapshot identifies possible reasons including blind practice, the fostering of word consciousness and the measure of self-directed learning used.

The study is exploratory in nature. Its findings reflect only the first trial unit of the smartphone-enabled curriculum. For the functional snapshot, the results must be interpreted with some caution. There were several limitations in the rigor of the test. Firstly, there was a short duration of 2 weeks between tests and what is reflected in the test may not be internalized by the students. Second, the presence of other helpers during the smartphone-enabled curriculum could have influenced results such as the additional attention paid to the student by the allied educator and curriculum designer. Third, the smartphone-enabled classes took the pre-test before which could have pre-conditioned them when they took the same post-test.

Nevertheless, there are several contributions to the study. First, it adds to the body of literature of mobile learning for younger students (Sandberg et al., 2011; Sha et al., 2012) by providing evidence for the effectiveness of smartphones for English language learning and self-directed learning in a classroom setting. It also adds to single method studies with its use of mixed methods to offer a deeper insight into understanding the behaviors and learning associated with a smartphone implementation in a curriculum. For smartphone use to become more widespread and effective, it is important to design the smartphone-enabled curriculum with pedagogical practice. The smartphone features alone cannot help the student learn without its pedagogical design in the curriculum. Also, if the teacher has not provided the foundational understanding of the concepts to be taught, the students will not be able to be self-directed. With basic conceptual understanding and pedagogical guidance, students can begin to exploit the advantages afforded by the smartphone.

Another contribution is the snapshot approach as a way of systematically analyzing the smartphone implementation in mixed methods research. This approach has not been used in this field, and its adaptation provides crucial junctures where the implementation can be analyzed in relation to other junctures. It is also a process-based approach which maximizes the use of the data collected and reduces the difficulty of integrating the data sets. We note that the snapshot approach is described in a sequential manner but in reality it could be iterative. Depending on how projects are designed, certain technologies do not reach the classroom or target users so fast as it could require a re-design of its features after feedback form the advanced infrastructure stage. Also, there could be cases where certain snapshots are missing. This then provides a weak picture of the whole implementation. Researchers, especially those using mixed methods, are encouraged to provide a full picture of such projects requiring the four suggested snapshots as a viable analytical frame in future work.

The smartphone has the potential to expand pedagogical practices into more efficient, more interactive and more student-driven learning. Smartphones cannot be left out of the classroom in the age when the world is increasingly technological driven and our students are becoming more tech-savvy. Its potential should be fully tapped for both in and out-of-classroom learning. Hence, it is vital that more studies assessing its usability and effectiveness for learning be conducted.

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