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Students' Participation Patterns in a Science Curriculum Supported by Mobile Technology

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Abstract: In this paper, we describe the enactment of a mobile technology-supported science curriculum that was designed with the aim of connecting the formal learning contexts with informal learning. Our study examines eight primary (grade) 3 classes that were taught by teachers using this science curriculum. We found out that amongst the different classes, the participation of students in doing the mobile learning activities differed somewhat. The analysis was based on studying the students' learning artifacts and the instructional feedback provided by teachers in the different classes. The results could potentially inform future curriculum design and implementation supported by mobile technology, as well as the supporting professional development of teachers.

Keywords: mobile technology, formal learning and informal learning, learning artefacts

1. Introduction

With advances in pedagogy design for mobile learning, the ways of integrating various mobile technologies into the curriculum have been extended and elaborated in some subject domains. Science has been one of the most prominent subjects in which learning has been enhanced by appropriating mobile technologies. With mobile learning, students experienced more opportunities for doing activities outside of the classroom, for example, conducting home-based experiments, observing characteristics of plants in the gardens or woods, collecting data on the water quality of the rivers, and submitting results or feedback after fieldtrips, etc. Thus, the activities carried out in the informal contexts could be better facilitated with the use of mobile technologies, particularly, the mobile apps or tools with different functions. However, the educational experiences for learners at home and other informal sectors is often in stark contrast to what is on offer in schools (Braund & Reiss, 2006), which leads to the limited evidence on what and how students are thinking and doing in the informal contexts. Further, the impact on students' learning in the informal context is still under investigation. To bridge the gap between learning in the formal contexts and informal contexts, and with the major purpose of exploring students' informal learning with mobile tools, a science curriculum supported by mobile technology (i.e. mobile phone with a learning system, MyDesk) will be briefly introduced. The various participation rates of students doing activities with mobile tools amongst the various science topics and the different classes will be analyzed. The study will inform the learning design of lessons deploying mobile technology in science education.

2. Literature

2.1 Formal Learning and Informal Learning

Hofstein and Rosenfeld (1996) contended that "it would be useful if science educators would consciously utilize a wide range of out-of-school environments which foster science learning". They preferred to adopt the "hybrid" view (rather than the dichotomy) view that informal learning experiences can occur in formal learning environments (e.g., schools) as well as in informal learning environments (e.g. museums, zoos). They recommended that future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science. Bell and others (2009) shared the same viewpoint that informal learning contexts should be seen as complementary to formal schooling rather than as in competition with it. Their report responds to the need for greater coherence and integration of informal environments and K-12 functions and classrooms, and the report urges a careful analysis of the goals and objectives of science learning in informal environments. Jones, Scanlon, & Clough (2013) found that there is little literature that considers the structures needed to support informal and semi-informal inquiry learning. Mortensen & Smart (2007) points out that although there is a growing effort to create partnerships between schools and informal learning settings, documentation of such projects is limited, and generally reported as examples of "best practices" with little discussion of challenges before or during implementation. Therefore, there are new questions about how and what aspects of formal and informal learning should be connected and integrated into the schooling system to be explored.

2.2 Mobile Learning in Science Education

With the advance of the Information and Communication Technology (ICT), mobile devices (e.g., smartphones, tablets, hand-held science sensors) have been absorbed into the fabric of our daily lives rapidly (Merchant, 2012). With mobile technology, the science learning environment can be mobile and move with the students to the field site, to the laboratory and beyond (Martin & Ertzberger, 2013). The extension of the learning environment enables students to investigate more science phenomena in real life and to demonstrate principles and scientific knowledge in different contexts other than the laboratory (Shih, Chuang, & Hwang, 2010). Furthermore, social networking opens up opportunities for students to do socially-mediated knowledge-building associated with learning science by doing science at anytime and anywhere. Science projects with the use of mobile technology have demonstrated the merits of mobile learning and its learning effectiveness for students (Pea & Maldonado, 2006). Mike Sharples et al. (2009) mentioned that mobile learning offers new ways to extend education outside the classroom, into the conversations and interactions of everyday life. The use of mobile devices blurs the distinction between formal and non-formal learning. According to Hwang and Tsai (2011), despite the multiple definitions of mobile learning, each focusing on a different aspect, they share the same idea, that is, the mobile device plays an important role in the learning activities no matter whether the activities are conducted in the field or in the classroom.

Recently, the most frequently discussed issues are the missing aspects of how students think, discuss, reason when they interact with the informal learning environments. Thus, more fine-grained analysis is needed to better understand the processes (i.e. sayings, doings and relatings) by which mobile technology merges into the learner's daily life, and to look into the ways in which technology is used and integrated in students' daily life (Rogers & Price, 2008).

3. Purposes and Research Questions

This study was conducted to answer the following research questions:

- How to connect classroom activities with out of classroom activities with mobile technology?
- How to capture students' learning in the informal contexts?
- What are the differences in the participation rates when students completed various mobile leaning activities?

4. Design of the Mobilized Science Curriculum

In M5ESC (Mobilized 5E Science Curriculum), learning design is facilitated by the 5E instructional model which has been frequently integrated with the science instruction in primary and secondary levels. The 5E instructional model refers to the doing of science learning followed by five inquiry phases: engage, explore, explain, elaborate and evaluate (Bybee, et al., 2006). The 5E allows students and teachers to experience common activities, to use and build on prior knowledge and experience, to construct meaning, and to continually assess their understanding of a scientific concept. When integrated with the use of mobile technology, the 5E inquiry learning goes beyond the walls of classroom. In the M5ESC, a learning system MyDesk is installed in the smartphone to facilitate students' learning with various mobile apps: KWL (a self-reflection tool), Notepad (a note taking tool), Blurb (a questioning tool), Sketchbook (a drawing tool), MapIt (a concept mapping tool), and Recorder (a voice recording tool). Classroom activities and out of classroom activities are supported and enabled by these tools. For example, students did an experiment on the property of materials (hardness, softness, strength, waterproof, etc) in the classroom and recorded the phenomena (i.e., using Notepad tool). Group work permitted students to work in collaboration in taking notes and discussing the phenomena (i.e., using Notepad tool and Recorder tool). Individual work is designed for students to input their reflections on their prior knowledge (i.e., using KWL tool). Students also participated in the out-of classroom and inquiry activities in field trips with the use of mobile apps. When they went back to the classroom, teachers reviewed their work and commented or graded their work (i.e., learning artefacts, reflections, and discussion) through the learning management system as the follow-up of students' activities in the informal context. This helps students to further elaborate their understanding and better connect the learning in the informal contexts and formal contexts. For more information about M5ESC, please refer to Looi, et al. (2014a), Looi, et al., (2014b). M5ESC provides students with various opportunities to engage in different types of activities and to build knowledge on the basis of inquiry in formal and informal learning contexts.

In addition, these tools are flexibly integrated with the learning activities with due consideration of the students' cognitive levels based on Starkey's digital learning age matrix. Level 1 (doing) activities include the use of NotePad or/and Recorder for collecting data and writing notes in field trips. KWL allows self-reflection on the connections between knowledge; hence it can be integrated into high cognitive levels of activities (i.e., level 2 - thinking about connections, level 3 - Thinking about concepts and Level 4 - Critiquing and evaluating). As an animation tool, Sketchbook is used to promote the students' ability to connect knowledge with daily experiences, and develop higher levels of conceptual understanding (i.e. level 5 - creating knowledge, and level 6 - sharing knowledge) through peer assessment of artefacts. Blurb is generally used to improve students' thinking and reasoning about the concepts through posing questions, which is appropriate for designing Level 2 and Level 3 activities.

With the above mentioned features, the M5ESC aims to promote students' conceptual understanding in science and develop crucial learning skills, such as self-reflection thinking skills, collaborative learning skills and self-directed learning skills.

5. Research Methods

5.1 Participants

All students in grade 3 (Primary 3) from a pilot school participated in the study of M5ESC. There were 8 classes with 310 students in 2013 school year. These students were divided into eight classes (3A, 3B, 3C, 3D, 3E, 3F, 3G and 3H). The eight classes were further divided by teachers into three levels of ability, named as HA (High Achievement Clasess A, B, C), MA (Mixed Achievement Classes E, F) and LA (Low Achievement Classes D, H) based on their prior achievements at the P1/P2 level. Five experienced teachers were responsible for teaching science for P3 science. As a pioneer future school in the use of ICT in education in Singapore, the principal and teachers placed great emphasis on the implementation of the innovation in their school, and they demonstrated their enthusiasm and passion towards the M5ESC development and implementation. They and their students had accepted the mobile learning as the routine in science learning both in and out of classroom. For example, when the teachers asked a question about a new concept, the students would bring out their phones to search the relevant information; when a student was doing an experiment, his or her partner took the pictures of the phenomena as the evidence; if the teacher asked students to do reflection, the students would prefer to write their reflection in the phone. Moreover, along with the curriculum implementation, an one-hour regular meeting was conducted on a biweekly basis for the teachers and researchers to share ideas on the lesson design, lesson enactment and elaboration. Thus, the M5ESC was iteratively improved by continuous cycles of teachers' implementations, and of interactions between teachers and researchers.

5.2 Topics of M5ESC in P3 science

Table 1 shows the topics and the number of mobile learning activities. There were 36 activities, with 8 KWL, 17 Sketchbook, 5 MapIT, 3 Blurb, 2 Notepad and 1 Recorder activities designed in the curriculum of all the topics. The number of the activities in each topic varied considering the content knowledge and the learning objectives stated in the national science syllabus. Therefore, with emphasis on developing students' self-reflection skills and self-directed learning skills, KWL learning activities were designed for each topic. The curriculum also proposed learning science through daily life experience, so Sketchbook activities which enabled students to connect links between daily life knowledge and knowledge learnt in the classroom were frequently designed. As for other tools, the activities were designed based on the learning needs of the topics.

Table 1. MyDesk learning activities in M5ESC

Topic	**MapIT**	**Recorder**	**Sketchbook**	**KWL**	**Blurb**	**Notepad**
Animals	0	0	4	1	0	0
Plants	1	0	3	1	0	1
Fungi & Bacteria	1	0	5	1	2	0
Materials	0	0	1	1	0	0
System	0	0	0	1	0	0
System-Plants	0	0	2	1	1	0
Body System	1	0	0	1	0	0
Digestive System	1	1	2	1	0	1
Total	5	1	17	8	3	2

5.3 Data Sources and Data Analysis

In this project, the data sources included observation sheets of teacher and students behavior in classrooms, transcripts of teacher and students discourses, and students' learning artefacts in and out of classroom. As the data collection followed the school schedule, each lesson in the scaling year of project was observed and analyzed. A huge database of project data was accumulated. In this study, students' learning artefacts were retrieved and analyzed for exploring students' responses to the mobile learning activities. For example, the number of each learning activity was first calculated, the completion rate (the percentage of the completed activities) of each activity was then generated for indicating the level of students' engagement in the different activities. A higher completion rate suggested more engagement in the mobile learning activities. Moreover, as we expected there should be differences among the topics, students' responses to the mobile learning activities in each topic were also analyzed. The class difference and correlation between teacher feedback-student activity performances were further analyzed to suggest the difference among the participation rates of the students' mobile activities. Descriptive analysis and paired samples t-test were conducted to explore whether these differences are statistically significant.

6. Findings

6.1 Differences in Mobile Activity Engagement

In 2013, MyDesk activities were designed and implemented in the whole cohort of P3. Overall, Table 2 shows that the completion rate of KWL was highest among all the activities designed (average class completion rate = 52.39%). This suggested that KWL was the most prominent mobile technology-based activity in all the classes with a high participation rate. Specifically, in some of the classes, all the students had finished the KWL assignments, with the class completion rate being 100%. Sketchbook activities also enjoyed great popularity with an average class completion rate of 36.31%. Students' participation in the MapIT and Blurb were more limited. Their average completion rates were very low.

We infer that students were mostly not familiar with these tools. Another key reason was that their teachers devoted most of time to the use of KWL and Sketchbook, and students had more opportunities to practise KWL and Sketchbook activities. Students were seldom engaged in activities on the Recorder and Notepad to support their learning. These all suggested that although mobile activities were designed in each topic, the participation rates of students in these activities differed.

Table 2. Descriptive statistics of MyDesk learning activities

MyDesk activities	N	Minimum	Maximum	Mean	Std. Deviation
Recorder	8	.00	.52	.0650	.18385
Blurb	16	.00	.44	.0581	.14372
KWL	56	.00	1.00	.5239	.33754
MapIT	40	.00	.60	.0550	.15091
Sketchbook	12	.00	.98	.3631	.31999
Notepad	16	.00	.48	.0588	.12154

6.1 Significance of the Activity Participation

Paired Samples t-test further confirmed the discrepancies in the completion rate of different types of activities. According to the statistics, KWL was the most popular. The completion rate of KWL was significantly higher than that of Recorder ($t=10.032$, $p < .000$), Blurb ($t=12.666$, $p < .005$), MapIT ($t=13.646$, $p < .005$), and Notepad ($t=13.056$, $p < .005$). Sketchbook, whose completion rate was the second highest, was significantly higher than that of Blurb ($t=7.408$, $p < .005$), Notepad ($t=7.134$, $p < .005$), and MapIT ($t=11.092$, $p < .005$). The test results also showed that there were significant differences between the use of KWL and Recorder, KWL and Blurb, Bulb and Sketchbook, KWL and Notepad, MapIT and Notepad, as the Sig. (2-tailed) were 0.000. Therefore, the differences amongst the use of tools were significant.

6.2 Different Responses to the Topics

Moreover, class responses to the mobile activities were also different. Take the topics of Fungi and Bacteria, and Digestive System as typical examples. Figure 1 shows that in the topic of Fungi and Bacteria, generally, the class average completion rate of the MyDesk activities designed for this topic was not very satisfying even though all classes to some extent attempted the activities. The highest completion rate was achieved by Class H (47.01%) which was a LA class. The second highest was attained by Class C (34.85%), which was a HA class. Class E and G had completed more than 20% of the activities. The class performed worst was Class D, with a completion rate of only 1.65%. The completion rate of different types of activities differed sharply. The KWL activity was completed most thoroughly, with the highest completion rate of 92.31% achieved by Class H and an average completion rate of more than 50% across classes. The second poplar was the four Sketchbook activities designed. All the classes had attempted this type of activity. Blurb and MapIT activities were rarely completed. There were several classes that left these activities untouched (e.g. Class B, E, and F).

In the topic of Digestive System (Figure 2), the completion rate, in general, was not very satisfying. Only one class out of 7 had attained a completion rate of more than 20%. The best performance was by Class A with a completion rate of 37.88%. Class D had the lowest completion rate of 4.32%. Among different types of activities designed, MapIT, Audio, and Notepad activities were hardly attempted in most classes. There was more participation in Sketchbook and KWL activities. In the KWL activity, the differences amongst classes were very obvious. The highest completion rate was 68.42% by Class F, yet there were classes (Class D and G) who did not finish the activity at all. Thus, the response of the same class in one topic was not consistent with the responses to other topics. These suggest that even in the same class, they had different participation rates of the mobile activities. We infer that influenced by teachers' lesson enactment and students' ability levels, class differences in the participation level of mobile activities existed.

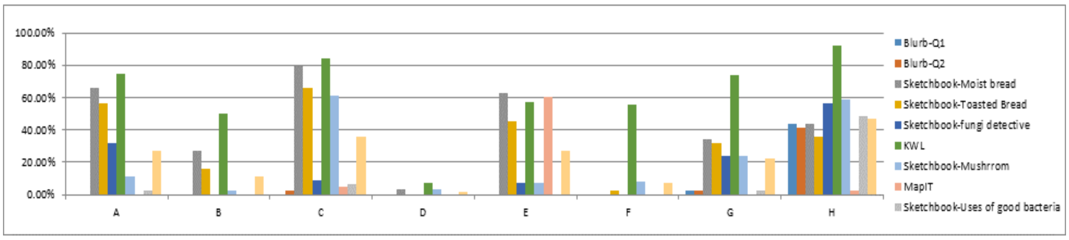

Figure 1. Participation rates of different classes for the topic of Fungi and Bacteria

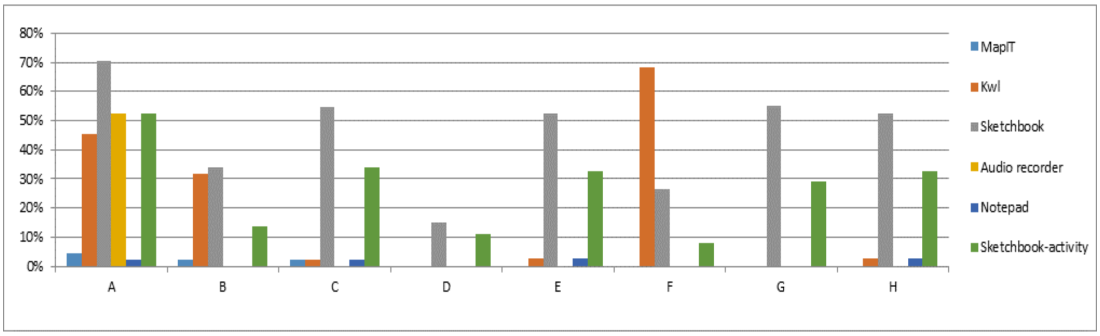

Figure 2. Participation rates of different classes for the topic of Digestive System

6.3 Differences in Class Responses

Figure 3 shows that among all the classes, HA classes A, B and C generally completed more mobile activities than the MA classes E, F, and G, while LA classes D and H generated comparatively less KWL reflections. For HA Classes, Class C contributed to more Sketchbook, Blurb, and MapIT activities. For the MA classes, Class E performed the most in all activities, while F completed the least MyDesk activties. LA class H performed well, especially in the Sketchbook, MapIT and KWL activities, providing a high completion rate on average. Thus, although HA completed more mobile activities in general, there were negative responses for Notepad and MapIT activities. MA class E performed better than the HA class A. This suggests that class ability may not the only key factor on students completion of the mobile activties, as other factors may further affect their participation rates.

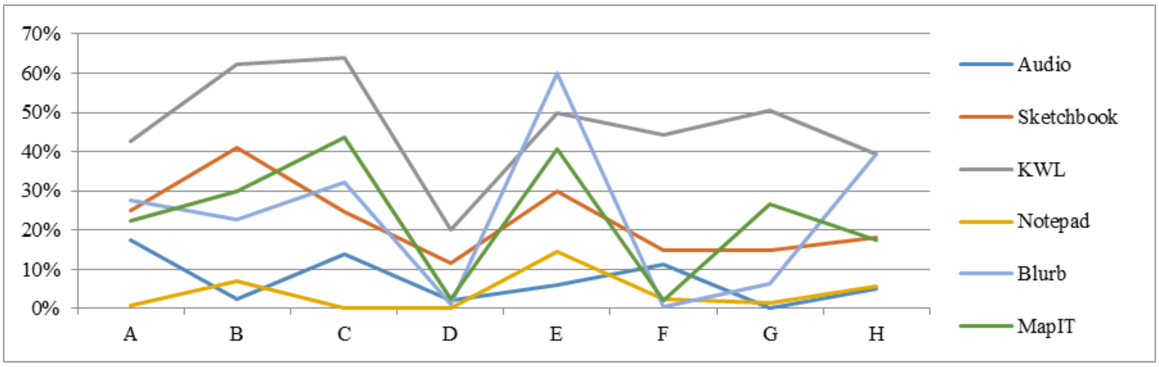

Figure 3. Class participation in the mobile activities

6.4 Teacher Feedback in the Mobile Activities

MyDesk allows teachers to grade and comment students' learning artefacts. In 2013, students' Mydesk activities involving KWL, Blurb, and Sketchbook, received more teachers' feedback compared to other activities. Table 2 shows that strong correlation was found between both Blurb's and Sketchbook's engagement and teacher feedback. Significant correlation was detected between KWL engagement and teacher feedback. This reveals that teacher feedback was one of the key factors that affected students' response to the mobile activities. This may help us explain why some MA classes complete more mobile activities than some HA classes as mentioned above.

Table 3. Correlation of teacher feedback and students' response to the mobile activities

Feedback to the activities	Correlation	
KWL2013P3-Feedback	Pearson Correlation	.276*
	Sig. (2-tailed)	.039
Blurb 2013P3-Feedback	Pearson Correlation	.997**
	Sig. (2-tailed)	.000
Sketchbook2013P3-Feedback	Pearson Correlation	.457**
	Sig. (2-tailed)	.000

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

For example, in the topic of Fungi and Bacteria, the rate of teacher feedback to the activities of this topic was in general lamentable, except for the teacher who taught class H achieved a satisfying 86.71% average feedback. Except for the MapIT activity in which the teacher did not provide feedback, the other activities all received good amount of feedback. The feedback to Sketchbook activities was all good at 100%. The teacher managed to provide feedback to 86.36% of Class B's work in KWL, but for other activities, the feedback rate was 0. Among these teachers, teachers who taught class C (feedback for 34.85% of activities on average), G (feedback for 21.64% of activities on average), class H (feedback for 47.01% of activities on average) performed most actively in providing feedback to the students. Being different from other teachers, the teacher who taught class H provided feedback for each mobile activity in the topic, leading to the equally high participation in the mobile activities in class H.

7. Conclusion

In conclusion, the study presented an exploration of the differences amongst classes in the students' use of mobile tools. The results indicated that although various mobile activities designed for the learning of science concepts, the participation in these mobile activities were varied because of students, class levels, and the teachers' feedback. Regarding to the differences in participation in the mobile activities amongst students, the researchers and teachers may consider providing more instructions for the students in doing mobile activities. Meanwhile, the teaching strategies on how to conduct the follow-up activities of the mobile learning and how to assess students' learning artefacts created by mobile tools are needed in teacher professional development. The results also suggested that the gap between lesson design and lesson enactment existed because of factors in and out of classroom. With the development of the mobile learning in both technology and pedagogy, calling for in-depth investigation on the value of mobile learning is necessary. Based on our research experience and the literature review of the recent relevant studies, future research should focus more on the exploration of the enactment of mobile technology-supported lessons/curriculum, with the aim of studying the factors that affect the teacher and students' behavior. The results or findings will inform the design and enactment of lessons supported by the mobile technology.

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