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ABSTRACT

Studying teacher enactment of an innovation helps us understand the process of effective spread of a curricular innovation to teachers who have differing levels of content readiness, pedagogical orientations, teaching competency, different student profiles, and professional development experiences. Towards this, we explore how different teachers in the same grade level appropriated a common science curriculum enabled by mobile technologies in their classrooms. The innovative science curriculum: Mobilized 5E (Engage-Explore-Explain-Elaborate-Evaluate) Science Curriculum was developed through an iterative cycle of design-based research. As curriculum designs were not self-sufficient by themselves, the enactments of the teachers differed in how they leveraged on students' artifacts, how they integrated the technology into the class, the ways in which they interacted with the students, and how they scaffolded students' activities in a mobile learning setting. In this study, the teachers' enactments of mobilized 5E lessons were observed, analyzed and compared, with the aim of exploring the differences of lesson enactment amongst them. The results showed that teachers' different pedagogical orientations affected their instructions, especially their ways of technology integration in the class, and their patterns of interactions with the students. Based on the exploration of the teacher enactment of the mobilized 5E curriculum, implications are drawn concerning the implementation of innovative curricula implementation and the supports for teacher professional development of such innovation with the ultimate purpose of sustaining and scaling.

Keywords: improving classroom teaching; pedagogical issues; teaching/learning strategies; mobile learning

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ABSTRACT

Studying teacher enactment of an innovation helps us understand the process of effective spread of a curricular innovation to teachers who have differing levels of content readiness, pedagogical orientations, teaching competency, different student profiles, and professional development experiences. Towards this, we explore how different teachers in the same grade level appropriated a common science curriculum enabled by mobile technologies in their classrooms. The innovative science curriculum: Mobilized 5E (Engage-Explore-Explain-Elaborate-Evaluate) Science Curriculum (M5ESC) was developed through an iterative cycle of design-based research for five years. As curriculum designs were not self-sufficient by themselves, the enactments of the teachers differed in how they leveraged on students' artifacts, how they integrated the technology into the class, and the ways in which they interacted with the students in a mobile learning setting. In this study, the teachers' enactments of mobilized 5E lessons were observed, analyzed and compared, with the aim of exploring the differences of lesson enactment amongst different teachers. The results showed that teachers' different pedagogical orientations affected their instruction, especially their ways of technology integration in the class, and their patterns of interactions with the students. Finally, implications are drawn concerning the implementation of innovative curricula implementation and the supports for teacher professional development of such innovation with the ultimate purpose of sustaining and scaling.

Keywords: Mobilized 5E Science Curriculum; Pedagogical Orientations; Technology Integration; Professional Development

INTRODUCTION

The literature on technology-based curricular innovations is packed with examples of pilot studies and proofs-of-concepts. It is rarer, in fact, in the literature, to see a project move through the various phases to where the innovation actually has become an integral part of routine classroom practices (e.g., Dede, Honan & Peters, 2005; Penuel, Fishman, & Cheng, 2011; Sabelli, 2008; Schneider & McDonald, 2006). Successful research intervention projects usually work with a few highly motivated teachers, but for long-term sustainability and scaling up of the innovation will require the average teachers to work with the designed curriculum and the proposed pedagogy (Penuel & Fishman, 2012). As the adoption of such a curriculum is not a one-to-one mapping of the designed curriculum to the classroom, teachers must always adapt it for their own use (Barab & Luehmann, 2003).

Unsuccessful implementation of curricular innovation is often traced to a lack of understanding of the role of teachers in playing a key role in making educational reforms successful (Dori & Herscovitz, 2005), and to a lack of knowledge of how to lead the teachers to implement the innovation in a way corresponding to the intentions of developers. Our review of relevant research work on mobilized curriculum suggests that relatively more research has been focused on the instructional design of mobile phone-facilitated curricula, the design of mobilized learning environments, and the learning effectiveness of mobilized curriculum (Gedik, Hanci-Karademirci, Kursun, & Cagiltay, 2012; Martin, & Ertzberger, 2013; Rau, Gao, & Wu, 2008). Less research is done on investigating the differences in teachers of curriculum implementation to inform the sustaining and scaling of the mobilized curriculum.

Mobilized 5E (Engage-Explore-Explain-Elaborate-Evaluate) Science Curriculum (M5ESC) is a product of our collaboration work with a primary school in Singapore. As the M5ESC was first developed and studied over a period of five school years (Looi, Zhang, Chen, Seow, & Chia, 2011), the researchers expected there must be many challenges and issues faced by science teachers at local primary schools who might not be familiar with the new instructional and learning approaches. To address the research deficiency on teacher enactment of mobilized curriculum, to expose challenges faced by different teachers in their enactments, and to ensure that the students receiving the curriculum could all benefit from engaging in the mobilized learning activities, it is necessary and essential for us to study how teachers adopt and adapt an innovation in their own classrooms (Puntambekar, Stylianou & Goldstein, 2007). Only through watching teachers' lesson enactments in detail could we get deep insights into how they enacted the designed lessons in the classrooms, whether and how their instructions facilitated students' learning as intended, and which aspects could be improved for successful implementation.

The literature review in this paper is targeted towards providing the theoretical background on the role of teachers in successful curriculum implementation, and on studying their classroom performances and their pedagogical orientations. This study uses a case study approach to examine the enactment of the curricular innovation by four teachers, especially on how they appropriate the curriculum based on their pedagogical beliefs, their perceptions of the students' needs and ability levels, and their perspective of the use of technology, as well as their classroom interactions with students. The findings point us to teacher differences on the lesson enactment and thus expose their deficiencies concerning the competencies required for M5ESC instruction. Meanwhile, the changes in teachers' pedagogical orientations and their performance in teaching practices over time could be detected to further illuminate teachers' appropriation of the curriculum.

LITERATURE REVIEW

Teacher Roles

Barab and Luehmann (2003) discuss issues of sustainability and local adaptation as crucial for scale. They describe the teacher's role in local adaptation as identifying local needs, critiquing the innovation in the light of those needs, visualizing possible scenarios of implementation, and finally making plans or decisions concerning the implementation. Teachers will be ultimately involved in the adoption, customization, and implementation process, and they are continually remaking and contextualizing the innovation in terms of their local context. Lessons learned from prior technology-based educational improvement research clearly indicate the importance of empowering teachers and building capacity to effect deeper changes in teachers' beliefs, knowledge, and practices (Fishman, 2005). Deep changes go beyond the superficial piecemeal changes in structures and procedures but work toward integrated changes in beliefs, norms of social interaction and pedagogical approaches enacted in teaching and learning practices (Coburn, 2003). Teachers are more likely to embrace and practice classroom innovations when they can see the connection between the use of technology, the learning needs of their students, and the content of the mandated curriculum.

The uptake of research innovations to real-world practices is generally low because few were robust treatments that addressed problems that seriously concerned practitioners (Dede, Honan & Peters, 2005). When robust designs that addressed serious problems of practice were tried, they had the potential to reach scale (Cohen & Ball, 2006). Based on Coburn (2003)'s definition of scale: scale can be defined as encompassing four interrelated dimensions of depth, sustainability, spread and shift in reform ownership. Notably, the depth refers to deep and consequential change in classroom practice, altering teachers' beliefs, norms of social interaction, and pedagogical principles as enacted in the curriculum. In Marx's (2012) comments on the issues of large-scale interventions in science education, he emphasized the focus should be paid on supporting teachers to be more effective in classroom instruction as students' achievement would be influenced by teachers' instruction significantly. Thus, the continuing emphasis of teachers' role in the curriculum implementation is an inevitable element of the research into innovation implementation and scale.

Teacher Enactment

In our review of current ICT-facilitated research, especially research on mobile learning, few focused on the long-term classroom observation of teacher enactment. Most current studies conducted short term or topic-based classroom observation (Clough, Jones, McAndrew & Scanlon, 2007; Ruchter, Klar, & Geiger, 2010) which were not adequate for observing teachers' overall performance on different instructional events, their changes (e.g. pedagogical beliefs), and student performance and achievement over time. As a result, how teachers use the planned curriculum in the actual classroom in the long term has been the crucial element in the implementation of an innovative practice. The failure of detecting the problems in the teacher enactment will probably lead to the desired effects being far from becoming a reality (Rodríguez, Nussbaum, & Dombrovskaia, 2012).

We have known for a long time that the model of getting to scale by just having a curriculum does not work, that it is a myth that "good" curriculum and teaching practice are self-explanatory and self-implementing for further scaling and implementation (Elmore, 1996). This model overlooks the complex process with which local curricular decisions are made, the entrenched political relationships that support existing textbook-driven curricula, the weak incentives operating on teachers to change their practices, and the extraordinary costs of "making large-scale, long-standing changes of a fundamental kind in how knowledge is constructed in the classrooms" (p. 19). Morris, et al (2011) attribute the variation in instruction in classrooms with teachers implementing the same lesson plan in different ways to differences in the expertise of the teacher or differences in the context that prompt teachers to change the plans.

Creating a curriculum as an ongoing process, the product of which is a composite of what is intended (planned curriculum), what actually happens (enacted curriculum), and how what happens influences those involved (experienced curriculum) (Marsh, 2009). Marsh proposes that desirable educational experiences arise when the interaction of these three curricula is flexible and evolving; and, therefore, it is not about "best" practices or "most correct" answers to fundamental curriculum questions.

Building on Marsh, we propose our conceptual model for the study of teacher enactment (see Figure 1). The planned curricular innovation is co-designed by participating pioneer teachers and researchers. This is then enacted by these pioneer teachers, and later on at a scaling stage, by teachers new to the curricular innovation. The enactment curricula is what the teacher does in the classroom, generating experiences and reflections to all those involved (the students and the teacher) as the experienced curriculum. Researchers as meso-level mediators interpret the experiences, processes and outcomes of the experienced curricular innovation, and work collaboratively and iteratively with teachers to refine and improve the planned curricula for more effective enactment and experiences in the next round of implementation (Looi, So, Toh & Chen, 2011).

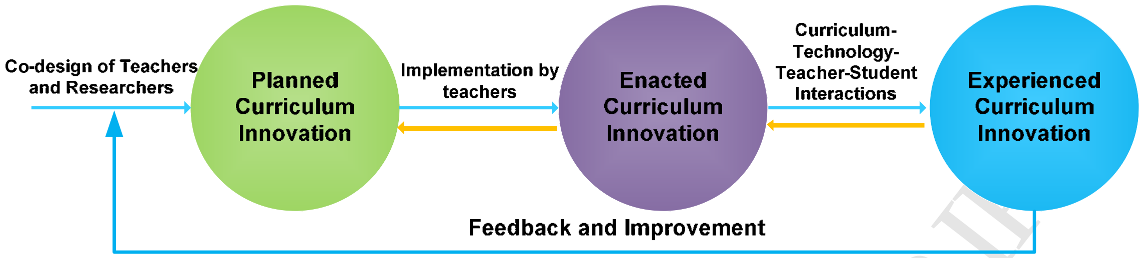

Figure 1. Conceptual Model of Enactment of Curricular Innovation

Teachers' Pedagogical Orientations

Much has been written about the impact of teachers' pedagogical beliefs and attitudes to ICT as "barriers" to ICT integrated teaching practice. Different types of pedagogical beliefs brought about different influences for classroom practices, such as teachers' questioning techniques, their use of technology and their patterns of interaction with the students (Prestridge, 2012). Teachers' pedagogical orientations, particularly in terms of whether a teacher is more strongly oriented to the student or to the curriculum, are connected to their pedagogical beliefs. Thus, studies frequently investigated the influence of teacher pedagogical orientations on their teaching practices.

Teacher pedagogical orientation generally is identified into two categories: constructivist pedagogical orientation and traditional pedagogical orientation (e.g. objectivist orientation, goal-driven orientation) (Becker & Riel, 1999; Hadley & Sheingold, 1993). In the constructivist-oriented class, teachers value collaboration, learner autonomy, generativity, reflectivity and active engagement. Students' construction of knowledge is enabled by active participation in discourse, collaboration, and student-centered activities rather than transference from teacher talk. The teachers elicit and use students' existing ideas as a basis for helping them construct new, more reasoned, more accurate or more elaborate understandings (Holt-Reynolds, 2000), and use technology as cognitive tool to support student-centered curricula (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). Whereas in the traditional class, such as objectivist-oriented class, teachers initiate a series of steps that lead inexorably to the production of intended and target knowledge. The direction of communication flow is mainly from teachers to students; student-centered activities are hindered because of the structures prevalent in the class; teachers value correct answers and take little account of students' individual ideas. Those with traditional beliefs use technology to support more teacher-directed curricula (Rahimi & Ebrahimi, 2011).

Thus, research has pointed to the necessity for finding the alignment between teachers' espoused pedagogical beliefs and their enacted beliefs in terms of classroom practices. Studies suggested that the difference between their espoused beliefs and the enacted beliefs can be another obstacle of the implementation of the designed innovation (Ertmer, et al., 2012). In the study reported here, exposing teachers' pedagogical orientations through observing their performance on instruction can provide valuable information whether there is a gap between the designed curriculum (constructivist pedagogy) and enacted curriculum, and whether teachers' own pedagogical beliefs resisted change after long-term implementation of the M5ESC.

RESEARCH PURPOSE AND QUESTIONS

We believe that more research on the "essential tensions" in the trajectory of adopting innovative practices in classrooms is necessary, as classrooms is a main venue for us to know the occurrence of the innovation and how it happens in the local context and how the teachers appropriate their beliefs, competency and knowledge to the new curriculum (Barab, Barnett, & Squire, 2002). Thus, critical instructional events which differentiate teachers' pedagogical orientations, their ways of integrating mobile technologies in lessons and the patterns of interacting with students, will be identified in the study. This relates to the successful implementation of the curriculum innovation which could help us to detect teachers' deficiency in the lesson implementation and their possible transformation of teaching patterns and strategies. The findings could inform and guide the curriculum implementation and teacher development of M5ESC in specific ways. The research questions are:

1. Are there any differences on teachers' pedagogical orientations, the way of technology integration and the patterns of interacting with students in the enactment of the same lesson plan of M5ESC? If yes, which are these differences?
2. How can the implementation of M5ESC be improved through addressing the problems in teacher enactment of M5ESC?

RESEARCH DESIGN

Mobilized 5E Science Curriculum (M5ESC)

As an innovative science curriculum, the M5ESC has attracted attention from many local schools with its unique design and development features, and its research-evidence-based learning effectiveness for students' science learning (Looi, et al., 2011). In M5ESC, mobile technology opens the door for a new kind of learning supporting learning anytime and anywhere that occurs when learners have access to information to perform authentic activities in the context of their learning (Martin & Ertzberger, 2013). The use of mobile technology particularly supports students' investigation beyond classroom for observing, recording and collecting data on scientific phenomena in the nature, as well as helps teachers trace and evaluate the learning process out of class.

To facilitate the seamless learning in inquiry (Looi, et al., 2010), the MyDesk mobile learning environment that runs on a Microsoft Windows Mobile operating system was developed for this research. MyDesk supports teachers in creating complete, coordinated, curriculum-based lessons that employ multiple media and applications (e.g., text, graphical, spreadsheet, animations, and the like). It facilitates them for evaluating students' artifacts through rating their quality levels and providing immediate feedback and comments. It is an environment in which students engage in the specified learning activities and create various artifacts using multifunctional mobile applications. MyDesk includes the following applications: KWL (for self-reflection), NotePad (a data recording tool), Recorder (a voice recorder tool), Sketchbook (a drawing-based tool), MapIT (a concept map tool), Blurb (a question setup tool). The combination of these tools in the MyDesk system aims to develop students' sophisticated and systematic understanding of scientific concepts and their modeling skills, reasoning skills and reflective thinking skills in various learning context, especially for them to foster self-directed learning skills in the activities beyond classroom (Brooks, 2009; Greca, & Moreira,2000; Lim, Lee, & Grabowski, 2009). Other supporting tools are integrated with the use of mentioned applications for facilitating various learning, such as built-in camera for taking photos, mobile blog and forum for online artifacts sharing and discussion, video/photo for fieldtrip and experiments, ColInq for geo-tagged postings, and search engine for collecting information from other sources. Equipped with MyDesk and these tools, students' science inquiry can be recorded, discussed and shared in the classroom or beyond the classroom.

In science teaching, the Ministry of Education of Singapore has advocated the use of the BSCS 5E Instructional Model (Bybee, 2002). In the 5E Model, the learning process of the students begins with engagement, moves to exploration, which is then followed by explanation, elaboration and evaluation. In studies conducted using the 5E instructional model, evidence repeatedly reveals that the model increases the success of students, elevates their conceptual understandings and positively changes their attitudes (Wilson, Taylor, Kowalski, Carlson, 2010). The integration of MyDesk into the 5E science curriculum is flexible based on the lesson content. Figure 2 shows a lesson unit on the topic of "Exploring Materials" in P3 science curriculum. The unit is organized using the 5E model and is incorporated with MyDesk and other supporting tools. The learning objectives are divided into two domains:

(1) Knowledge domain:
   a. List some materials and relate their properties to their uses, e.g. wood, metal, rubber, plastics, fabric, ceramic, glass;
   b. Relate the properties of materials to their uses;
   c. State the different properties of materials;
   d. State the ways to test the properties of materials;
   e. Identify the appropriate materials to use for different objects based on what the objects are used for.

(2) Skills domain:
   a. Develop skills in designing fair experiment;
   b. Enhance skills in comparison and observation;
   c. Improve collaborative learning skills and reflective thinking skills.

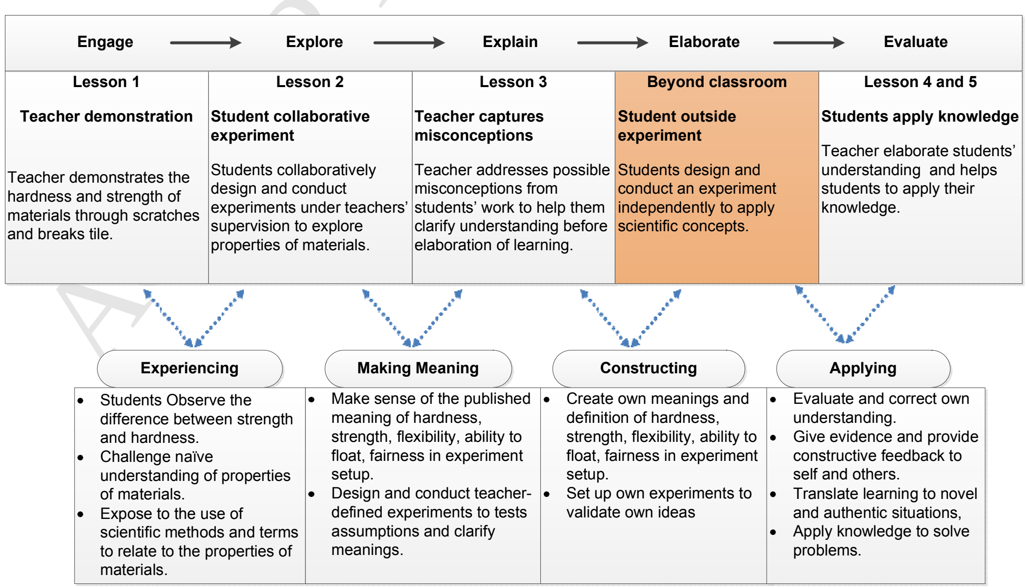

Figure 2. A Lesson Plan (learning activity) from Perspective of 5E Instructional Model

Figure 2 shows the lesson unit spanning over 5 lessons including some home activities after Lesson 3. The top part of the figure describes the main activity in the lesson organized by the 5E instructional model. The bottom part describes the cognition level of learning when the students participate in the designed lessons. In the Engage and Explore stages of the 5E model, teachers design and enact lessons to engage students in the topic and to explore students' misconceptions and guide them to explore the relevant knowledge and to develop inquiry skills (e.g. photo and video taking, KWL, Recorder, Blurb). In the stages of Explore and Explain, the students try to create meaning by making sense of their experiences (e.g. KWL, NotePad, photo and video taking, Recorder, Sketchy™, MapIT). They attempt to clarify ideas and meanings and then elaborate their understanding they encountered during such experiences. Different from other science curriculum, we assign home activities for students to further investigate the materials and their properties around their daily life using smartphone, and to demonstrate their current understanding and construct new knowledge of materials with relating to the daily life experience (e.g. KWL, Blurb, NotePad, photo and video taking, Recorder, Sketchy™, ColInq). After participating in a series of inquiry activities, students' understanding and learning skills will be finally evaluated through problem solving (e.g. KWL, note taking, MapIT). The progression and work quality of the students' work can be reviewed and evaluated by the teacher.

Context

In the co-design process of lessons of M5ESC, researchers working with the teacher Jodie revised and mobilized two years' worth of the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by ubiquitous access to mobile devices. During the trial instruction of the lessons, to support the long-term learning activities, 34 students from the experimental class were each assigned a smartphone with 24x7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection and geo-tagging in the neighborhood, home-based experiments involving parents, online information search and peer discussions, and digital student artifact creation, among others.

Because of the positive outcomes of the pilot run of the curricular innovation, the school principal decided to scale up the implementation from one class to all 8 classes of Primary 3 in 2012. These included three high ability classes, three mixed ability classes, and two low ability classes[1], and involved six teachers[2]. Besides Jodie, the other five teachers were new to mobilized curriculum (while some have attended workshops). An assistant (called an Allied Educator) supported each teacher in the technology aspects in the classroom. As the curriculum was to be scaled to all classes in the level and by teachers new to it, a committee comprising the new teachers, Jodie and the subject head Sharon was formed to meet on a weekly basis. The school used this TTT (Teachers' Time-Tabled time which enabled the teachers to meet as a professional learning community) for the participating teachers to have the meetings of this committee (McDougall & Squires, 1997). They met weekly at a set-aside time to review, revise the lesson plan, discuss and seek consensus on the proposed teaching strategies of the specific content for the

[1] There are about 300 students in P3 (Primary (Grade) 3). They were divided into different levels according to their scores at the end of P2. 43.3 % of them were identified as high ability students, and 21.3% of them were identified as low ability students respectively.

[2] There were six teachers for these eight classes, and they included the teacher in our initial study. Four teachers started the implementation at the beginning of the academic year, while the other two teachers were assigned later to join the implementation a few months later.

forthcoming science lessons and adapt it to fit into the classes of different abilities and cultures which the teacher of each class was familiar with. In particular, they put efforts on discussing how the curriculum might be customized for different ability students and yet at the same time retained the design intent of the curriculum.

The researchers acted as participant observers of the process of scaling-up implementation in the school. They observed the professional development process (e.g. workshops, TTT discussion, trial instruction) with which the teachers learned more about the curricular innovation, the materials and support they were given, and the teachers' enactment in the classroom. They also acted as participants in the implementation plan: they served as meso-level agents by actively offering suggestions, guidance and support to help the teacher better implement the curriculum in the subsequent lessons (Looi et al, 2011). The findings of the research analysis, namely, feedback on questioning skills and patterns of interacting with students were communicated back to the teachers to support their self-reflection in the TTT discussion on their own teaching.

Participants

In this study, we focused on case studies of the first four teachers: Emily, Helen, Serena, and Jodie who implemented the curriculum in our pilot school. Case study is an effective approach to describe, explore or explain the objects and the relevant events and it would help to present more details on teacher difference on the lesson enactment (Tobin, Kahle, & Fraser, 1990). Teachers all had willingness to participate in teaching and developing the curriculum. Before the scale-up implementation, they had previously attended six one-day workshops on the use of the suite of learning apps on the smartphones, and on familiarizing themselves with the pedagogy of M5ESC. Prior to it, they had not practised or conducted any 5E lessons using the smartphones. General information of the four teachers' backgrounds and the classes they taught were depicted in Table 1.

Table 1. Teachers and their classes' information

Teachers	Years of Teaching Experience	Year of Mobilsed 5E curriculum	Grade Level	Class ability and class size
Emily	11	1st Year (2012)	P3	One higher ability (n=43) and one lower ability class (n=39)
Helen	4	1st Year (2012)	P3	One mixed ability class (n=41)
Serena	12	1st Year (2012)	P3	One higher ability (n=43) and one lower ability class (n=25)
Jodie	6	2009, 2010, 2012	P3	One higher ability class (n=44)

Data Collection and Data Analysis

Both naturalistic and qualitative data were used to gain a holistic vision of curricular implementation by different teachers. The data was mainly collected from classroom observations. Data sources included field notes, observation sheets and video and audio transcripts. At least one researcher attended each class during the use of the curriculum and conducted classroom observation. During each class, the researcher set up a video-recorder at the back of the class to record the class proceedings, and took a mobile video camera to capture group performance and teacher-student interactions. Teachers' talk and each group work was audio recorded. More specifically, using field notes, the key instructional events and main activities were recorded. With classroom observation sheets, the researchers pointed out how the teacher enacted lessons related to key instructional events (e.g. questions, hand-on activities, experiments, mobile phone activities) and in particular, how the teacher facilitated the class activities following students' work on the smartphones.

During classroom observations, the researchers focused on: 1) the teachers' performance on questioning (e.g. whether they posed open-end questions or closed-ended questions;, instruction of key concepts and their responses to students' questions and activities (e.g. whether they interacted frequently with students, and whether they used students' ideas to develop their understanding of the knowledge) (Kawalkar & Vijapurkar, 2013); 2) the ways of technology integration in the class (e.g. whether they integrated mobile technology in student-centered or teacher-centered technology) (Ottenbreit-Leftwich et al., 2012); 3) the patterns of teacher-student interactions (e.g. the frequency of interacting with individuals or the class; the types of scaffolds they provided for the students). In the class, scaffolds were the important form of assistances provided by teachers, which could help learners accomplish task within their zone of proximal development (Vygotsky, 1978). In addition, teachers' feedback on the proposed teaching strategies and their espoused pedagogical beliefs was examined in the weekly TTT discussion transcripts.

The findings were discussed and assessed to evaluate teachers' competences on the use of technology in the class and their teaching strategies on facilitating students' various activities. These can help reveal teachers' pedagogical orientations toward the traditional beliefs or constructivist beliefs (An & Reigeluth, 2012), and to further expose teacher differencess. Moreover, to visualize the details of teacher enactment of lessons in real class, we mapped out their performance on mediating learning by counting the frequency of the exploratory questions and the scaffolds (e.g. scripts, prompts and challenging students' ideas) in the lesson episode (Gillies, 2006; Ge & Land, 2004; Morris, et al., 2010), and by analyzing the contents and recipients (individual or class levels) of these questions and scaffolds. This analysis can illuminate teachers' patterns of interacting with their students (Chiu, 2004). In situations in which the recipient is meant to be the whole class, the teacher's intention is to assist the whole class without identifying individual student's specific requirements. If the recipient is meant to be different students, the teacher's focus is on identifying students' specific misconceptions or requirements, and providing immediate feedback for guiding the students' to reach the solutions. The latter indicated the teacher respected student-generated ideas and attempted to understand them through interactions with the students rather than providing feedback for the whole class. Such a strategy can especially benefit the low ability students (King, 2002). The analysis of questions and scaffolds was based on reviewing and categorizing teachers and students' verbal behavior in the video and audio transcripts. Four types of teacher verbal actions (exploratory questions, scripts, prompts and challenges to students' ideas) are identified, and their frequencies counted for each teacher.

Concerning reliability of the data analysis, the two lead researchers first examined the data, and did the coding individually and then collaboratively in order to reach consensus regarding the coding of teacher and student verbal behavior, their patterns of interactions, and their performance on the key instructional events and mobile learning activities. They checked and negotiated any discrepancies, and sought consensus to align the coding and make the final decision. Thus, there was no disagreement in the description and discussion of findings presented here. To further visualize their differences in the enactment of the planed lessons, we identify and account for these differences through observing the following lessons on the topic of materials as we mentioned above. The lessons consist of two consecutive periods in the classroom and one home activity (Table 2).

Table 2. The general information of the lesson implemented

5E Stage	Class Activity	Home Activities
Explore	Students design and conduct fair experiments to test properties of materials. Students to observe and compare experiments designed by peers. 1. **Design Experiment** • Teacher revisits definitions of strength and hardness on the flipchart and students' responses on KWL. • Teacher invites students to define flexibility and ability to float as characteristics of materials. • Teacher asks the students to design experiments to test for hardness, strength, flexibility and ability to float in different materials. 2. **Conduct experiment and collect data** • Teacher asks the students to conduct experiments they designed. • Students record the experiments using smart phone. • Students take notes of the experiments using smartphone. 3. **Share data** • Students share findings from experiment via blog and forum.	Students relate their understanding learned from classroom with their experience out of classroom. 1. **Identify the materials** • Students take pictures of materials used in their daily lives using smart phone. 2. **Relate the properties and their value of the materials** • Students describe the purpose of the identified objects and explain the properties of the materials used to suit the purpose through Sketchy. 3. **KWL reflection** • Students update the KWL to reflect their learning, especially on their thoughts on fairness of experiment.

FINDINGS

Contextualizing the curriculum is ultimately a local phenomenon (Squire et al, 2003), and is the result of factors such as teacher's goals, teacher's pedagogical values, students' ability levels, students' needs, and other local constraints (Roehrig, Kruse, & Kern, 2007). Though the same lesson plan design was presented to the four teachers, each of the teachers adapted the plan to focus on different aspects of the science learning that were congruent with their epistemological orientation and pedagogical beliefs, and based on what each believed was relevant to the ability level of their class. Based on the classroom observations and data analysis, we attempted to identify teachers' variations on lesson implementation through describing their pedagogical orientations on the instruction (Voogt, 2010), their patterns of the technology integration into teaching practices and their strategies on dealing with the instructional events and interacting with the students. Here, teachers' pedagogical orientations were identified together with analyzing their responses to instructional events, and their behavior towards the learning goal, learning objectives, questions and process skills (Faikhamta, 2013).

Teacher Differences on Pedagogical Orientations

Teacher's belief was identified as the most important influence on what they practice in the classroom (Carlson, 1994). In this innovative curriculum, teachers' pedagogical orientations, which are affected by their epistemological orientation and pedagogical beliefs, were examined and exposed through comparing their performance on the instructional events. This analysis provided a window into teachers' personal beliefs that influence the enactment of M5ESC and the impact of this on the students' responses. This could help draw recommendations for the pedagogical approaches of the M5ESC. Overall, four teachers performed differently on their pedagogical orientations. Four categories of pedagogical orientations were identified ultimately, and different inclinations towards traditional teaching methods (more teacher-guided instruction) and constructivist strategies (more student-centered instruction) were detected and analyzed (Means & Oslon, 1997). This showed that teachers had different pedagogical beliefs before their curriculum implementation. After teaching the M5ESC for a substantial amount of time, some of them transformed their pedagogical beliefs from traditional objectivist orientations to more constructivist orientations.

Emily's Objectivist Orientation

In this scale-up implementation, Emily taught two classes - one higher ability and one lower ability classes. With 11 years of science teaching experience, Emily was skillful in classroom management, especially for instruction in the lower ability class. In the class, she usually spent some time in controlling the class discipline through traditional ways (e.g. waiting for the students to be silent, staring at the misbehaving students). After requiring students to strictly follow her instruction, she would evaluate and assess the students' knowledge with an objectivist orientation.

In several teaching opportunities, we observed in her class, she seemed not to have tapped on such opportunities to probe students' reasoning processes in greater depth. For instance, she usually directly corrected the students' misconceptions as manifested from their KWL and other written work. When she posed questions or assigned activities, she did not create a discussion environment around these opportunities as compared with student-centered practices in which the teacher acted more as a facilitator than an instructor for guiding students' discussion, reasoning and thinking in the learning process (Jones, 2007). In contrast, she frequently asked closed-ended questions followed by providing the answers to the students to correct their misconceptions instead of addressing the rationale behind their misconceptions, or challenging their naive understanding through asking exploratory questions (Cohen, 1994). When conducting students' collaborative activities or experiments, Emily preferred to walk round to check students' results without being involved in the students' discussion and investigating their process. Although she thought that she believed in constructivism as expressed in the TTT discussion, her espoused and enacted beliefs appeared to be not well-aligned (Berg, Benz, Lasley, & Raisch, 1998). In Emily's class, students received few opportunities to practice their ideas and skills by themselves in a more open and free environment and to share the findings with other groups by themselves. In most cases, Emily refined and assessed students' work for the whole class. It was also observed that there was no instructional differentiation and enactment between the two ability groups she was teaching. While she might not have the skills to facilitate peer discussions or exploratory questioning, she did perceive the need to improve her questioning skills, and the competency to design different inquiry activities for students with different cognitive levels (Wenning, 2005).

Helen's Goal-driven Orientation

As a teacher with least teaching experience in science (four years), Helen taught a mixed ability class in which there was a wide variation in the students' academic abilities. From observations of her general performance on the instruction of M5ESC, Helen's pedagogical orientation could be identified as goal-driven, with an emphasis on achieving goals (e.g. skills and knowledge) rather than on the learning process (DeShon & Gillespie, 2005; Krajcik, McNeill, Reiser, 2008). In seeking the alignment of the proposed lesson plan sequences and the actual lessons, she attempted to manage the class and evaluate students' activities in a structural and sequential way. Devoting more efforts to guiding the class activities following the designed lesson plan, she tended to align the classroom activities with the planned lessons through controlling the steps and duration of the activities. She managed the class through providing lectures and guidance. Thus, instruction occurred frequently and was targeted at the whole class level. Small-group or individual instruction occurred less often (Cuban, 1983). In sum, Helen tended to conduct a teacher-guided class with the apparent orientation towards achieving learning goals, although the lessons plan was proposed to integrate more student-centered collaborative activities (Ertmer, 2001).

Closely observing her instruction, we found that as a very structured lesson planner, she set her pace in the classroom, and allowed little time for students to buzz, explore and discuss. When she presented and evaluated students' work, she had clear expectations of students' possible misconceptions or responses, and preferred to act a guide or a leader for gear students into the designed direction but with the provision of limited opportunity for students' recognizing by themselves. If she identified a misconception, she would wait for the planned moment in the lesson plan to come up before addressing it. For example, when she presented students work at MyDesk using projector, she would choose the typical artifacts she thought could reflect most students' misunderstanding. Then she would steer her classroom discussion in her planned speed so that she could deliver her planned objectives and hear the students mention the keywords/ phrases. When students' response or evolvement of ideas beyond her expectation, she interrupted or ignored students' discussion or their responses. When she was walking round to review students' collaborative work or experiments, she preferred to stand by for a little while with discussing with students who might have questions or constructing low quality work. This further indicated that she tried to avoid the occasions that might "waste" her class time. We also found that she did not differentiate her instruction to cater to the various students' abilities. On more than one occasion, she taught science in a traditional and delivery mode, taking responsibility for deciding the content, the pace and linking the big ideas together through teacher-guided strategies, such as lecturing.

Serena's transformation from Objectivist to Constructivist Orientation

Serena was a teacher with 12 years of teaching experience. In this scale-up implementation, she taught two science classes: one higher ability and one lower ability class. Notably, although she was a beginning teacher of the M5ESC, she deployed different levels of scaffolding for these two different classes. The enactments of her lessons were also different in the two classes. In the higher ability class, she acted more as a collaborator and facilitator for assisting students' investigating and complete inquiry activities by themselves. In the class, she asked a series of guiding questions and provided appropriate scaffolds (e.g. scripts) for students to construct their deep understanding of knowledge and reasoning to achieve the consensus solutions (Gillies & Boyle, 2005). While in the lower ability, she intended to provide more layers of scaffolds (e.g. prompts, challenging ideas) for reminding students' in knowledge, activities procedures and work division in the collaborative activities and experiments (Pifarre & Cobos, 2010). The instructional differentiation allowed her higher ability students to explore the topic in a much greater depth compared with her lower ability students. Moreover, her involvement in the students' discussions and her provision of assistance were also more frequent in the lower activity class. Compared to Helen and Emily, Serena would like to spend more time exposing students' problems and listening to students' explanations to detect their misconceptions and guide them to reflect upon their understanding changes after inquiry activities. She usually posed a series of open-ended questions for prompting students to elaborate the solutions in pairs when she was presenting and assessing students' work.

An interesting finding was noted in the implementation process. In Serena's first few lessons enacting the M5ESC, her teaching demonstrated objectivist orientations as well. Similar with Emily and Helen, she intended to control the class at most occasions in order to strictly follow the lesson plans and ignored the students' individual requests for assistance. She focused more on the whole class process and results than on groups or individual work. Although pedagogical belief has been defined as a stable and strong brief which is not easily changed, it does not mean that they cannot be changed (Nespor,1987; Prestridge, 2012). Positively, with frequently interactions and discussions with the researchers and other teachers during TTT, as Serena got more familiar with the 5E instructional principles and gradually understood the underlying pedagogy of M5ESC, she demonstrated some shift of her pedagogical orientation from a teacher-centered, traditional-transmission view, to a more constructivist model that focused on procedures and student learning rather than stressing the results. Compared to the performance of other teachers in TTT discussion, Serena more actively and frequently provided various ideas on how to improve the implementation of the M5ESC based on her rich teaching experience. She would share her new ideas and research papers she read recently with other teachers. She also attempted to refine the proposed teaching strategies in the TTT discussion and articulated her intention to practice them in her class. For example, she sought to connect ideas for students based on their ideas and artifacts, asked students to describe and reflect processes in science, and sought to clarify students' thinking processes. In addition, she required students to apply science to their lives and connect their understanding with their real experience using smartphone (e.g. collect data in the form of images, upload the reflections and notes, video record of the scientific phenomena), and to develop students' lifelong learning skills which were also considered as part of the constructivist teaching strategy (Stofflett & Stoddart, 1994).

Jodie's Constructivist Orientation

In the scale-up implementation, Jodie taught the class with the highest ability students. Being the teacher who was involved in the earlier research, Jodie was most familiar with the curricular innovation and understood the underlying principles of the M5ESC. More constructivist teaching strategies were identified in her class. As was observed, the learning objectives of her lessons had been extended to include other learning skills that might not emphasized in the syllabus (e.g. reasoning skills, and critical thinking skills). For example, before she conducted a collaborative activity, she tended to pose leading questions and expected to students' answers or questions. Then she followed up on questions posed by the students in her class and sought to construct knowledge with the class from these questions instead of providing students with correct answers. When students were doing their experiments, she frequently interacted with students and provided them with scaffolds. She focused more on diagnosing knowledge understanding than just mere reviewing of learning artifacts (Figure 3a). Students had more opportunities to discuss with Jodie and their partners in the collaborative activities as Jodie involved frequently in students' peer discussion (Figure 3b).

As a teacher, she herself was curious about science and was not afraid to admit that she did not know. She acted as a participant and mediator and not a leader in the class inquiry. In exploring the meaning of what students said, she took a genuine interest in students' interpretation of science terms and challenging their ideas through asking questions. In addition, she did not enforce a planned lesson, and would follow the students' learning pace and needs. Thus, Jodie could be identified a teacher who understood to use constructivist strategies (e.g. using students' ideas, providing scaffolds, challenging ideas, conducting group discussions) to guide and assist students' learning and inquiry, and focused more on developing crucial learning skills in steading of emphasizing on remembering and understanding the subject knowledge (Wildy & Wallace,1995).

Figure 3a. Jodie facilitating students' collaborative work
Figure 3b. Students doing collaborative work

Table 3 shows the distinctive utterances of teachers in each of these orientations which we gathered from the classroom discourse data. In the objectivist approach, the teacher focused on getting the students to know the concepts, definitions or ideas. This was often characterized in the discourse by pointing or directing the students to what the teacher wants the students to know. The teachers tend to transmit or direct the students to what was the correct answer they should know. In the constructivist style, the teacher helped students to construct their understanding, by making their thinking visible through their questions. She asked the students to tell her what they thought instead of what they knew, clarify their thinking and ask for students to explain or give evidence.

Table 3. Objectivist vs Constructivist Styles of Classroom Discourse

Objectivist questioning styles	**Constructivist questioning styles**
"I tell you"	"You tell me"
"Listen to me", "Look here"	"What do you think your friend is trying to say?"
"If you are quiet, I cannot teach!"	"Is it true? Share what you think?"
"This is your answer"	"You can dislike my answer but provide justification (evidence)"

"Let's explore the good answer your friend shared just now"	"Lynn said that and Peter disagreed. Let's explore what could have caused their disagreement."
"What is the problem with the variable chosen in this experiment?"	"The results of these 2 experiments are different. Can you compare them and tell me which is a better setup?"

Use of Technology

With different pedagogical orientations, teachers' perceptions of technology integration in their science instruction also varied based on classroom observations. The major difference was reflected by their ways of incorporating the technology into their classroom teaching. Table 3 presents the strategies in which they used the technology or technology-related learning artifacts in the instruction of materials in the mobilized 5E science curriculum. We discriminated the ways they used technology as either teacher-guided strategies (Bielefeldt, 2012) or student-centered strategies (Kerawalla, Petrou, & Scanlon, 2013), for further comparing their orientations on the integration of technology in science curriculum. As we can see in Table 3, from Emily's class to Jodie's class, more and more student-centered strategies of technology integration were conducted, this further reflected teachers' pedagogical orientations on the use of technology in the class. The findings were aligned with the analysis of their pedagogical orientations discussed in the previous sections.

Table 4. Teachers' ways of the technology integration into the class

Teachers	**Ways of the use of technology**	**Teacher-guided**	**Student-centered**
Emily	Evaluation tool	√	
	Homework Assignment	√	
	Delivering correct answers	√	
Helen	Monitoring the progress	√	
	Evaluation tool	√	
	Identifying misconceptions	√	
	Delivering key concepts(lecture)	√	
	Guiding discussion and thinking		√
Serena	Evaluation tool	√	
	Demonstration	√	
	Identifying misconceptions	√	
	Hands-on activities		√
	Reflection tool		√
	Guiding discussion and thinking		√
Jodie	Monitoring the progress	√	
	Evaluation tool	√	
	Identifying misconceptions	√	
	Conducting collaborative work		√
	Guiding students' discussion and thinking		√
	Reflection tool		√
	Comparison tool		√
	Supporting collaborative work		√

Technology Use in Emily's Class

In the enactment of the lessons, Emily would consolidate the KWL responses and displayed them via the class projector at the start the lesson. She reviewed quickly students' work and randomly chose several students' work for discussion. She first attempted to draw the students' attention to key concept: the importance of knowing materials based on students' understanding, during which she asked leading questions that require specific responses to meet her objectives. Different from Helen, she spent less time on discussing students' work in KWL and she preferred to take their work as an assignment and intended to provide correct answers or her final answers for the whole class. Thus, she did not build upon the students' ideas about the materials they had expressed in their KWL. Though she used the KWL as a tool to surface pupils' misconception and prior understanding, her purpose was to correct the students' misunderstanding by providing the answers to them. In Emily's class, technology-related work was more act as a homework assignment, and she acted more as a reviewer for checking the results without more explanation or exploratory questions. There no significant difference on the patterns of technology use in the two classes.

Technology Use in Helen's Class

Before class, Helen had reviewed and graded students' work done in the MyDesk. Helen consolidated students' inputs from KWL to help her plan and structure her lesson before the lesson itself. She would consolidate the pupils' KWL submissions on a PowerPoint presentation slide, and highlight the typical responses and discussed the misconceptions on the properties of materials during class time. By interpreting the students' work, she organized her teaching to help her deliver her planned objectives. She would correct the misconceptions of the students and used them as opportunities to introduce the key concepts she wanted the students to know. Thus, she used KWL as a tool to evaluate students' learning artifacts and surface their misconceptions and to correct their misconceptions by providing the canonical answers. Meanwhile, she concentrated on practicing students' thinking skills through question-answer pattern. She has expressed that she felt rather burnt-out when she had to follow the students' interest and pace of learning. However, she did reckon that this was a more effective way for the students to learn. She liked to anticipate students' responses and prepared for them in advance. The similar integration pattern was found in her use of the MapIT and Sketchy, they were used frequently as an evaluation tool of students' conceptual understanding, and delivering relevant concepts and opportunity for students' discussion. Students' use of the other tools in smartphone were strictly guided by Helen's instruction, they were not required to use then without her approval. As a result, students' had limited room of using their smartphones to collect data in other activities.

Technology Use in Serena's Class

In the lesson on materials, instead of getting the students to start their KWL on materials at first, Serena sought to engage them in through doing a scratch test on a piece of ceramic tile. Using Socrative.com, she asked students to post their prediction on what would happen when she scratched the glazed and unglazed side of the tile[3]. Serena asked the children to post the reasons why there were no scratches on the

[3] Socrative.com is a smart student response system in which student responses are visually represented for multiple-choice, true/false and short answer questions. The reports can be viewed online as a Google spreadsheet or as an emailed Excel file.

unglazed side on Socrative.com. She encouraged her students to produce their own explanations and sought to understand their reasoning instead of giving them the answers directly. In Serena's class, she also presented an experiment video recorded by smartphone for demonstrating the flexibility of the materials. A series of questions were posed with the demonstration. After students had further understanding of the properties of materials, Serena referred to students' work at KWL and asked students to explain and reflect their work individually or collaboratively. Furthermore, she had the students spend some time taking pictures of objects in the school. During class, she would display the pictures taken by the students to discuss the materials used in the objects, their properties and how the objects are used. Thus, she sought to leverage on the opportunity to connect the students' understanding to the experience in daily life, and more student-centered mobilized activities were designed and conducted in her classes. In summary, different from Helen and Emily, Serena focused more on students' reasoning process of the questions and intends to create more opportunities for students to do hand-on activities or experiments and to apply their understanding in nature environment.

Technology Use in Jodie's Class

Different with other teachers, Jodie required students to fill in KWL in the class. Then she looked through the students' KWL responses and presented the typical work in different quality levels with asking series of questions based on their work. Similar with Serena, she used Socrative.Com to address students' problems in their KWL, and asked students to work in pairs to share their thoughts with other groups (e.g. the meaning of properties with some examples) through Socrative. When students were working together, she was involved in several groups for providing assistances on knowledge and guiding them to participate in evaluation and discussion. She observed that students posted wood and metal as examples of properties and addressed students' understanding of properties. She asked students the importance for them to know the properties of materials and asked the students to post why they must know and learn about properties of materials in the KWL. After these activities, most of students revised and elaborated their reflections on the KWL. In the end of the lessons, Jodie returned to the KWL responses which she chose at the beginning of lessons for presenting students' changes on the conceptual understanding of materials. In addition, when she conducted students' collaborative activities, she reminded students to use video taking tool to record their process and important findings when their partners were doing the activities. Hence, Jodie provided more opportunities for students' inquiry and collaboration with the design of more students-centered activities. Students could use smartphones in the activities more freely and flexibly than other classes.

Teacher-Student Interactions

To visualize the differences among four teachers' interaction with their students, we compared their performances and roles as facilitators in the classroom interactions. In the study, we identified the scaffolds provided for the students as the methods to mediate the learning, such as scripts, prompts, exploratory questions and challenges to student ideas (Weinberger & Fisher, 2006; Ge & Land, 2004; King, 2002). Below is the representation we mapped out for visualizing the differences of teacher-student interactions in the lesson episode. In Figure 4, the columns represent the major instructional events in the lesson of materials, and the rows represent the level of teacher-student interaction (the teacher interacting at the class level or at the individual student level). The different shapes refer to different types of verbal interactions. The frequency of each verbal interaction is the number shown in the centre of the shape. Figure 4 provides valuable information on the kinds of scaffolds provided by the teachers when they interacted with students in different instructional events, how they facilitated students' problem solving and whether they addressed individual students' ideas through responding to or scaffolding specific individual students.

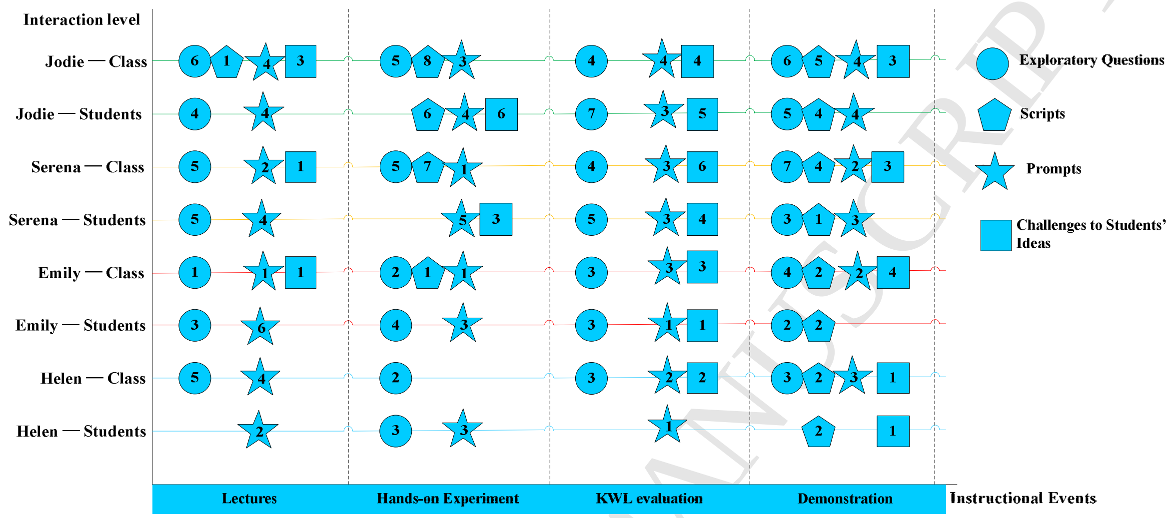

Figure 4. Representation of teacher-student interactions

Figure 4 shows the differences in teacher-student interactions that could be detected. In Table 5, we calculated the total number of each type of teacher-student interactions.

Table 5. The number of each type of teacher-student interactions

Teachers	Exploratory questions	Scripts	Prompts	Challenges to ideas
Helen	16	4	13	2
Emily	22	5	17	9
Serena	34	12	23	17
Jodie	37	24	30	21

Teachers like Jodie and Serena used more constructivist strategies, provided more scaffolds for students and were more involved in students' activities in their classes. The frequency of interactions reached to 112 in Jodie's class and 86 in Serena's class. Teachers Emily and Helen, who were used more traditional strategies, spent more time on lecturing and were less involved in students' activities. They had lower frequencies of teacher-student interactions in their classes (Helen: 35; Emily: 43). Specifically, Jodie and Serena were involved more in students' work and tended to provide appropriate scripts and prompts for the students to find the solutions by themselves. More questions to investigating students' knowledge and identify misconceptions were posed in their classes. Thus, teachers performed differently in asking exploratory questions, challenging students' ideas and offering immediate and appropriate scripts and prompts. These all impact the implementation of the mobilized curriculum.

The highest frequency of teacher-student interaction appeared in Jodie's class (teacher-class level: 60; teacher-student level: 52). In her efforts to introduce or explain the key concepts of the materials, she posed a series of exploratory questions (37) for guiding students to attain the knowledge (lectures: 10, hands-on experiment: 5, KWL evaluation: 11, and demonstration: 11). A considerable number (16) of the questions were targeted at individual students for probing their current understanding, or identifying their misconceptions. The findings indicated that Jodie was skillful at designing and implementing the exploratory questions, and she preferred to listen to her students and provide them with new knowledge based on their prior knowledge. See the following excerpt:

Jodie: Are you trying to say it is not flexible? If it is not flexible, what should be used?
Jodie: Why don't you use metal, is there is something special about wood?
Jodie: Why do people choose the glass, even it is broken easily. Is that because is harder?

One significant difference between Jodie and other three teachers was found that Jodie provided more scripts for scaffolding students' hands-on experiments (14) and demonstrations (9). These helped the students to construct higher quality work. See some excerpts below:

Jodie: Each of you tests two properties of materials. When you partner do the experiment, you record the experiment. You use video to record your partner's work.

Jodie: How is the plastic? What is flexible? How to test the plastic? Pass the materials to your partners. Remember to use video camera to record the work.

Another difference was that Jodie divided the experiment of testing four properties of materials (e.g. hardness, for hardness, strength, flexibility and ability to float) into four small hands-on activities, each with scripts (14) and instructions. She emphasized the work division and purpose of the task. Conversely, the common strategies of other teachers were to elucidate the purpose of the experiment before the students started their work. In the process, they neglected to emphasize the script flow to guide students to conduct the experiments. Few scripts were offered during the hands-on activities (Serena: 7; Emily: 1; Helen: 0), leading to failure on the part of some of the low ability students on completing the task.

When students were doing their activities (i.e. the hands-on experiment), Jodie detected their difficulties and was involved in their discussion with providing prompts (4) and challenging their ideas (6). Most students were engaged in their activities and did the appropriate roles in the task. Thus, Jodie could successfully act as a guide, facilitator and mentor in students' activities, which led to students' actively participation in hands-on activities and other learning activities. Serena was also walking around to check students' work, and was involved in assisting students to solve problems (prompts: 5, challenging students' ideas: 3). Other teachers, Emily and Helen, were less involved in students work because of their pedagogical orientations. They spent more time on introducing and explaining the key conceptions, providing the correct answers, repeating the rules for doing activities, as well as managing the class (e.g. class discipline).

In summary, students will benefit more in the class which has more student-centred activities and provides more opportunities for students' inquiry and investigation by themselves. If the teacher could act a facilitator and mediator in students' work, provide appropriate scaffolds for students to do their work, and enable students to integrate the smartphone tools to capture their activities and data, the gap between designed lessons and enacted lessons will be eliminated gradually.

DISCUSSION

Building on (Marsh, 2009), our study of the four teachers enacting the designed M5ESC in primary level provides a vivid illustration of their enaction of the curriculum in an ongoing process, as interactions between what is intended (planned curriculum), what actually happens (enacted curriculum), and how what happens influences those involved (experienced curriculum). The enactment experiences of the teacher together with the educational experiences of the students evolve with the sharing and reflections of the teachers, and with the researchers acting as meso-level actors to guide the teachers to reflect on their teaching enactments, their beliefs, and their skills. Teachers had benefited from this long term curriculum implementation and the associated relevant supports. The changes in two teachers on their pedagogical orientations and their competencies on instructing M5ESC suggested the positive results of the long-term intervention.

As proposed in the M5ESC, we encouraged the teachers to transform their traditional beliefs into constructivist beliefs through using more constructivist pedagogical strategies in the instruction of lessons, such as asking more exploratory open-ended questions, interacting actively with students to probe their current ideas and help them to construct new ideas or knowledge. Teachers were expected to offer various scaffolds for students to do hand-on experiments and participate in the mobile learning activities to enable students to attain relevant skills and the knowledge. They were also required to design and apply the mobile technology (MyDesk and other supported tools) in the student-centered activities. Besides, weekly TTT discussion was conducted for teacher reflections on the improvement of teaching strategies, and for researchers to bridge the gap between the proposal, principles and pedagogy and teacher enactments in the classroom. In their curriculum implementation, teachers with different experiences of M5ESC exposed their differences in their pedagogical orientations, the patterns of use of technology and the ways of interacting with the students. This helps answer the first research question.

Although results of studies showed expert teachers had sets of personal theories and beliefs about classroom practices arising from past experiences that were deeply rooted and resistive to change (Wilson, Miller & Yerkes, 1993; Lumpe, Haney, & Czerniak, 2000), some teachers experienced difficulty in changing their traditional pedagogical beliefs, This was reflected by our analysis of two teachers, Helen and Emily, who struggled to embrace the constructivist instructional strategies presented in M5ESC that deviated from their science pedagogical orientations. Their enactments of M5ESC could not manifest the underlying principles of M5ESC as proposed in the designed lesson plans. We inferred the reasons as follows: 1) As the two teachers were new to the M5ESC, with their traditional beliefs, they were more prone to adopt the lessons in the traditional way. 2) They did not fully understand the pedagogical value of M5ESC and mobile learning in science education in comparison with other teachers (Hermans, Tondeur, van Braak, & Valcke, 2008), and this can lead to the failure of integrating mobile learning activities in M5ESC. They thought their instruction could facilitate students to achieve the target learning goals defined in their syllabus as well, thus they put less effort on conducting more mobile activities to develop students' crucial learning skills. 3) During TTT discussion, they sometimes resisted accepting the constructivist teaching strategies as they felt very constrained by the limited curriculum time and students' ability levels. 4) Although long term TTT discussion encouraged teachers to reflect their lesson enactment and sharing new ideas with other teachers, it seemed that the sharing opportunities were not equally appropriated for each teacher.

However, from Serena's case, we found that pedagogical beliefs could be transformed in the long term curriculum implementation with active participation in the professional development sessions. It would be not the issue for the teachers who were thought to resist changing their personal beliefs. Moreover, as a leading teacher who practiced M5ESC for longer time, Jodie's lessons provided a vision of the best practices of M5ESC with constructivist pedagogical orientations. Jodie would like to capture students' ideas and use these ideas to prompt students' deep understanding; she acted frequently as a collaborator and facilitator to assist students' learning activities. She offered various scaffolds for students' completing the learning activities and constructing the understanding of relevant understanding. More importantly, Jodie opened up more space for integrating the mobile technology into the student-centered activities in science curriculum.

Ertmer (1999) defined two types of barriers of technology integration in teaching practices, first-order (external) and second order (internal) barriers. The first one referred to the condition of ICT integration, such as equipment, training and support. These should be not an issue for M5ESC curriculum implementation as the school received full support from Ministry of Education, the school leaders as well as the science teachers and researchers. Various typess of professional development training including workshop, TTT discussion and iterative pilot instruction supported teachers' transformation of pedagogical beliefs from traditional to constructivist orientation, PCK of science curriculum, TPACK of M5ESC and their practical skills (Graham, Borup & Smith, 2012; Mishra & Koehler, 2006; van Driel, Verloop & de Vos, 1998). Meanwhile, the school was equipped with fast speed wireless and each student was facilitated with a smartphone, thus ensuring that students could have an access to their mobile phone activities any time at school and continue their work at home considering all Singapore families had wireless. Therefore, the impact brought by the first order barrier could be mostly eliminated.

The second order barrier relates to teachers' beliefs about teacher-students roles and the classroom practices including teaching methods, organizational and management styles and assessment procedures. As we found out in our classroom observations, teachers with different pedagogical orientations had different ways of technology integration. In the classroom of teachers with traditional pedagogical orientation, they intended to conduct more teacher-guided mobile activities. The technology was used to support the traditional roles of delivering information, assigning homework and monitoring progress, while for teachers whose beliefs had been transformed to constructivist beliefs, they valued the use of the mobile technology in more student-centered activities. As we discovered, the mobile technology not only acted as information resources, but also evaluation, reflection, comparison, and collaborative tools in the class. These could have been identified as activities with requirements of high cognition levels. They were likely to promote students' knowledge construction, and develop other crucial learning skills (e.g. reflective learning skills, critical thinking skills and collaborative learning skills) (Starkey, 2011). The findings and comparison on the ways of technology integration suggested that teachers should recognize the value of technology integration in the various activities, and extend the scope of such technology integration to support students' effective learning. This will further inform the PD training and help teachers to come over obstacles from the external barrier of technology integration.

On observing teachers' performance on interacting with students, teachers had different tendency on scaffolding students in the classroom. Comparing to the constructivist-oriented teachers, traditional-oriented teachers might provide less scaffolds for students, instead, they emphasized on the guide for the whole class, and they usually neglected individuals' requirements and assisted them without identifying the problems or misconceptions. They mostly asked closed-ended questions and created limited opportunities for students to answer the exploratory questions. These were the challenges of teachers faced in the curriculum implementing which referring to their teaching skills on how to scaffold students' activities in M5ESC, and these will be addressed in their PD as well. Adaptations were also necessary in mixed ability classes where a variety of academic abilities was present. The same principles of inquiry and constructivism applied across the level. However, the higher ability students needed more challenges and the lower ability students needed more scaffolding and concrete experiences than the middle ability students. These findings would inform our lesson design, teacher professional development and curriculum implementation in the subsequent stages.

IMPLICATIONS

A productive view to change management in transforming teaching practices is to assume that individuals who are attempting to implement changes will continually need clarification about them to make sense, and to assume that people will only change of there is pressure to do so, a supportive environment, and opportunities to share experiences with others in similar situations (Fullan, 1992). By working with each individual teacher and with the team of teachers, a clearer clarification of what the mobilized curriculum means for them and how to enact it, emerges for the teachers. Informed by the study, the following improvements will be done by further efforts of teachers and researchers.

In curriculum design, working with the teachers, we decide to differentiate the lesson plan for different ability groups. For example, all classes in the entire level conducted experiments concerning the test of materials but the lesson procedures will be different with some differentiation in the instruction. Improvement on the design of mobile learning activities for different ability students will be proposed in the lesson elaboration. For the low ability classes, the teachers are encouraged to design simple mobile learning activities with lower ability and cognition requirements, such as using mobile applications to do the tasks (e.g. collecting data, writing notes), and to reflect upon the understanding of concepts in the activities (e.g. answering some questions). While, for the higher ability classes, the requirement of higher cognition levels such critiquing, evaluating and sharing the learning artifacts will be incorporated into the design of complex learning activities (Starkey, 2011). This will highlight the value of mobile technology in the science instruction for knowledge construction and prompt the effective learning as well (Cox, Webb, Abbott, Blakeley, Beauchamp, & Rhodes, 2004).

During implementation, teachers faced challenges on questioning techniques, responding to students and scaffolding students' activities. Through classroom observations, researchers and more experienced teachers will provide support to other teachers by giving personalized feedback addressing the above challenges particularly after each lesson enactment. Teacher sharing facilitated by the researchers in the weekly TTT meetings will focus more on discussing questioning skills, the ways of providing scaffolds and the ways technology is used. Professional development can be facilitated by lesson enactment via modeling by a teacher or researcher, and by lesson study discussions on recorded classroom sessions. We will encourage more teachers to do reflection on their lesson enactment in the sharing sessions (Taitelbaum, Mamlok-Naaman, Carmeli, & Hofstein, 2008). While researchers provide these initial scaffoldings, the plan is to build up the capacity of this group of primary 3 science teachers so that they can sustain the innovation in the coming years with fading from the researchers in the subsequent year. In leveling up the capacity of the teachers, some new activities will be planned. Arrangements will be made for teachers to observe their peers conducting the lesson activities.

In conclusion, our analysis of the journey of the teachers' enactment of the designed technology-enabled curriculum helps us to explore the interplay between the technology-enabled curriculum, the teacher's pedagogical beliefs and habits, and the teacher's growth. In summary, this work is a contribution to helping us understand the process of effective dissemination of a technology-enabled curricular innovation to teachers who have differing levels of content readiness, pedagogical orientations, and different student ability groups.

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- different teachers appropriated a mobilized science curriculum
- their enactments were observed, analyzed and compared
- pedagogical orientations and student ability levels affected their instructions
- teachers need to move and be supported from designed curriculum to enacted curriculum