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# Developing a Professional Development Model for Science Teachers to Implement a Mobilized Science Curriculum

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**Abstract:** In our work on scaling a mobile technology-facilitated science curriculum called Mobilized 5E Science Curriculum (M5ESC) in a Singapore primary school, great efforts have been devoted to developing a teacher professional development (TPD) model of this curriculum innovation to facilitate teacher enactment of M5ESC in primary schools. In the study, we present the process of professional development for M5ESC and propose a continuing stage-based TPD model for promoting teacher changes on the implementation of M5ESC. Data analysis on a leading teacher's performance and students' work suggested that teacher's pedagogical belief has been transformed into the constructivist orientation influenced by the long term participation of TPD for M5ESC. This is evidenced by her patterns of interacting with students, her use of technology, and her students' active involvement in the student-centered activities.

**Keywords:** Mobilized 5E Science Curriculum, Teacher Professional Development, Constructivist Orientation

## 1. Introduction

As a curriculum innovation, the Mobilized 5E Science Curriculum (M5ESC) has been researched and implemented in a Singapore primary school over a period spanning five years. The implementation of this mobile technology-facilitated science curriculum at the school brought about significant changes for both teachers and students. With the intention of scaling M5ESC to other schools, various efforts have been devoted to developing appropriate teaching materials, student work sheets, assessment instruments and a teacher professional development (TPD) model. Among these efforts, TPD was most focused, which was the key component for scaling the M5ESC. Based on literature review, there are limited studies conducted using fine-grained analysis of teachers' practices to understand the affordances of the TPD communities for teachers' changes and limited evidence suggested that teachers who participated in a community experienced positive changes in their attitudes and practices with technology. This paper details teacher changes as part of an effort of a long-term, school-based and continuing TPD community, namely, PD for M5ESC. The study firstly describes the features of the M5ESC, and then presents the principles of effective TPD and the introduction of how the TPD community runs. One leading teacher's class was selected and analyzed to collect evidence for the impact of TPD on teacher performance and student achievement. The findings help to inform the development and research of TPD for implementing mobile technology-facilitated curriculum.

## 2. Mobilized 5E Science Curriculum

As an innovative science curriculum, M5ESC was developed and elaborated progressively through a design-based research approach. In M5ESC, the lesson design is based on the 5E (Engagement-Exploration- Explanation- Elaboration- Evaluation) instructional model and integrated with the use of various mobile applications (i.e. MyDesk system) (Bybee, 2002). MyDesk supports teachers in creating complete, coordinated, curriculum-based lessons that employ multiple media and applications (e.g. text, graphical, spreadsheet, concept map, animations, and the like). It facilitates them for evaluating students' artifacts through rating their quality levels and providing immediate feedback. Uniquely, the MyDesk system includes the following applications: KWL (self-reflection), NotePad (taking notes), Recorder (recording voice), Sketchbook (drawing), MapIT (concept map tool), Blurb (question setup tool) which aim to cultivate students' sophisticated and systematic understanding of scientific concepts and develop 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 (Greca, & Moreira, 2000; Lim, Lee, & Grabowski, 2009; Brooks, 2009). Other supporting tools are combined with the use of mentioned applications for facilitating various learning, such as built-in camera for taking photos of fieldtrip and experiment, mobile blog and forum for online artifacts sharing and discussion, and search engine for collecting information from other resources. In sum, 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). This facilitates students' science inquiry in "seamless" learning environments, namely, a continuity of the learning experience across different scenarios or contexts (Looi, 2010). Hence, the use of mobile technology particularly supports students' investigation beyond the 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.

## 3. Professional Development Model for M5ESC

Based on literature review, the optimal features of TPD can be built on with following key ideas: First, it should recognize that the reciprocal relationship between TPD and accountability in that the teachers must give consent to what they are being asked to do and the strategies for doing it (Elmore, 2002). Thus, TPD is not a stable and short term working session; it is an interactive and recursive continuum with complex reaction among multiple factors. Second, it must take into account differing needs of different teachers (Stein et al., 1999), and create opportunity for teachers to expose their deficiency, sharing their challenges and learn from each other to peruse the common solutions to the problems and forge consensus about the actions they might take for improvement. Therefore, a learning community is proposed to enable various collaborative activities, particularly those focusing on curriculum and instruction (e.g. lesson plan, teaching strategies, students' achievement, and assessment) (Scribner, Cockrell, Cockrell, & Valentine, 1999), which involves critical, reflective and negotiate dialogue on the disagreement or challenges. Finally, the stage-based model of TPD with situated learning in teacher needs is advocated. The study of most effective TPD models has indicated that the stage by stage with different emphasis and forms of activities facilitates teachers in developing competencies. Teacher growth is closely aligned with their involvement of stage-based TPD. Thus, following the principles of optimal features of effective TPD model, a TPD model was proposed and gradually developed with the progress of M5ESC implementation and scaling within 3-year period. The development stages of TPD for M5ESC are described as Figure 1.

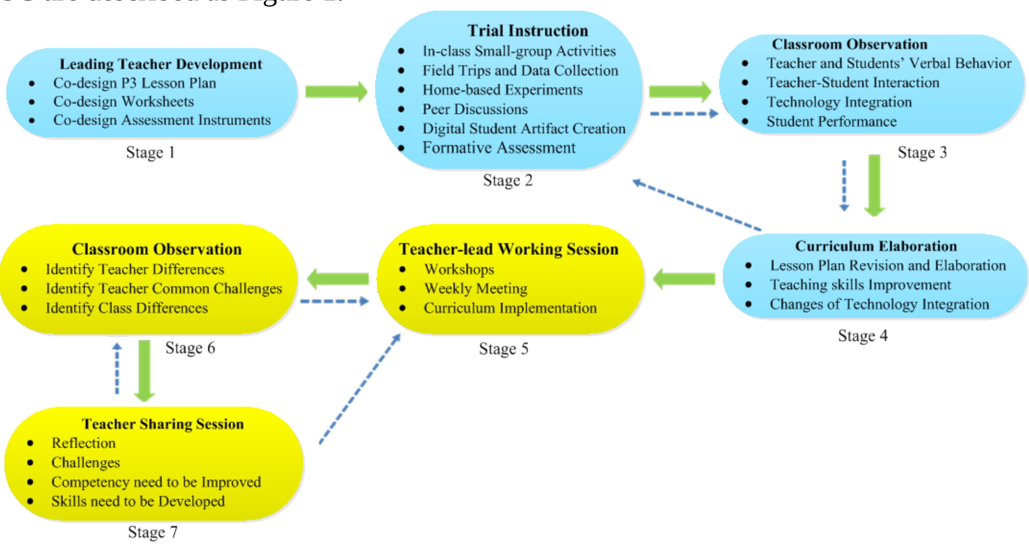

Figure 1. Teacher Professional Development Model for M5ESC

Our model advocates the evolution of TPD as closely related to teachers' instructional practices, the collaboration between researchers and teachers on curriculum development and elaboration, and teachers actively and centrally involved in decisions (Day, 1999). The TPD was built to be a continuous flow of different parties' engagement occurring in two phases: phase I-trial implementation phase (From stage 1 to 4) and phase II-scaling phase (From stage 5 to 7). The phase I is intended to develop the mobilized 5E lesson exemplars and prepare for the consequent PD phase. The phase II emphasizes the development of teachers' competency of M5ESC instruction and the transformation of their pedagogical belief on technology-facilitated curriculum towards constructivist (Ballone & Czerniak, 2001).

At stage 1, one leading teacher Jodie (head of science project with six-year teaching experience) was selected to co-design the curriculum materials with researchers. She has strong willingness to join the project and expects teacher change with participation of long-term TPD. After completing designing each topic (six topics at P3 level were designed), trial instructions of these topics were conducted by Jodie. Two researchers stood by and observed teacher performance in the classroom with focusing on teacher and students' verbal behavior, the patterns of teacher-student interaction, the organization of student activities, the way of technology integration and students' responses and performance, which had been frequently discussed as the major indicators of teacher change (An & Reigeluth, 2012). Data analysis on the above aspects was followed by the classroom observation. The evidence was also collected for detecting the inconsistence between actual teacher performance and expected performance in the lesson design, exposing gaps in the instruction and running of the activities. The results were used to inform curriculum elaboration at stage 4. Meanwhile, immediate feedback and comments of the improvement on both curriculum and instruction were provided to improve the lesson design and subsequent enactments when the teacher finished lessons at one class.

Because of positive outcomes of the pilot run of the M5ESC, the school principal decided to scale up the implementation from one class to all 8 classes of Primary (Grade) 3 in 2012. Besides Jodie, the other 5 teachers were new to the mobilized curriculum. A teaching assistant (called an Allied Educator) was employed to support each teacher in the technology and activity aspects (e.g. mobile applications, experiments, videos, and handheld technology) in the classroom. As the curriculum was to be scaled to all classes in the level and by teachers new to this curriculum, a committee (stage 5: teacher-lead working session) comprising the new teachers, Jodie and the subject head Sharon, ICT head and curriculum planner, researchers and programmers was formed to meet on a weekly basis (McDougall & Squires, 1997). We found this factor to be influential in establishing ownership that positively influenced the teachers' approach to curriculum development and their level of engagement. As a leading teacher of the committee, Jodie provided valuable information on the instruction of M5ESC, the principles of organization of learning activities and the patterns of proposed constructivist practices of technology integration. In the working sessions, 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 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. Additionally, workshops targeting at developing teachers' pedagogical knowledge of 5E and skills of technology use were conducted for supporting new teachers' better alignment of their lesson enactment. Researchers made numerous visits to classrooms during implementation to support teachers and make observations on implementation success and fidelity (e.g. detecting the problems and identifying the challenges and their differences on the enactment). Moreover, some novice teachers' classes were selectively observed by experienced teachers together with researchers. Following by the classroom observation, teacher sharing sessions were regularly conducted for discussing the problems detected and the possible improvement on the competency and skills according to teachers' reflections and researchers' observation and feedback. Especially, critical pedagogical reflection about teaching and learning which has to be seen as an integral part of the teachers' professional development emphasized in our TPD. In TPD, teachers negotiated the possible solutions to the problems between the traditional assessment and the formative assessment of M5ESC. Thus, as a PD community, our TPD is built on the principles of optimal features of TPD model which accommodates the active and frequent interaction between researchers' feedback, teachers' practices and students' responses. Through participating in the TPD, teacher change and growth are assumed to reach with the long-term iterative lesson enactment, student achievement and performance will arrive at higher levels after being engaging in student-centered activities frequently.

## 4. Purposes and Research Questions

Building on an understanding of the underlying pedagogy of M5ESC, practice of the M5ESC in the classroom, and participation in the continuing TPD community, the teacher practices in science education move toward more participatory and constructivist-oriented approaches (Nelson, 2009). Thus, the fundamental changes evolving from an emphasis on teacher-centered instruction to student-centered learning is proposed to be observed in the classroom. Therefore, the following research questions were addressed to identify the influence of TPD on teacher enactment of M5ESC.

- How did the TPD for M5ESC change a teacher over time?
- What were the changes of the teacher's pedagogical orientations on the instruction of M5ESC?

## 5. Methods

### *5.1 Teacher profile*

In the study, we selected the leading teacher Jodie as the target teacher for data analysis. The selection depended on the below justification: a. the teacher should have rich teaching experience, this guaranteed she had adequate content knowledge and common teaching skills of instructional event (e.g. students activities, experiments, demonstration) and class management skills; b. The results of relevant studies showed expert teachers had sets of personal theories and beliefs about classroom practices arising from past experience that were deeply rooted and resistive to change (Wilson, Miller & Yerkes, 1993), they performed difficulty in changing their traditional pedagogical beliefs although they had espoused beliefs, such as constructivist belief. From observing changes of the expert teacher, the evidence might be more persuasive. As a leading teacher, she had joined the project since 2009. She was teaching one higher ability class (n=44). She had strong willingness on teacher changes through long-term TPD, she expected that instruction transformation would take place with active involvement of TPD over time.

### *5.2 Data Collection and Data Analysis*

Both naturalistic and qualitative data were used to gain a holistic vision of curricular implementation by the teacher. At least one researcher attended each class during the use of the curriculum and conducted classroom observation. The researcher also 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. Each group work was audio recorded. The data collection was focused on how the teacher enacted lessons related to key instructional events (e.g. questions, hand-on activities, and experiments) and in particular, how the teacher facilitated the class activities following students' work on the smartphones. Thus, during observations, the researchers focused more on the teacher and student interactions, the teachers' responses to students' questions or answers, as well as the ways in which the use of the mobile technologies was integrated in the class. The researcher wrote field notes to record the lesson sequences, and the major teacher and student behaviors in the instructional events. The lessons of "Exploring Materials" were selected as the target topic for the data analysis (Table 1).

Table 1. 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. | Students relate their understanding learned from classroom with their experience out of classroom. |

| | | |
|---|---|---|
| | 1. **Design Experiment**<br>• Teacher revisits definitions of strength and hardness on the flipchart and students' responses on KWL.<br>• Teacher invites students to define flexibility and ability to float as characteristics of materials.<br>• Teacher asks the students to design experiments to test for hardness, strength, flexibility and ability to float in different materials.<br><br>2. **Conduct experiment and collect data**<br>• Teacher asks the students to conduct experiments they designed.<br>• Students record the experiments using smart phone.<br>• Students take notes of the experiments using smartphone.<br><br>3. **Share data**<br>• Students share findings from experiment via blog and forum. | 1. **Identify the materials**<br>• Students take pictures of materials used in their daily lives using smart phone.<br><br>2. **Relate the properties and their value of the materials**<br>• Students describe the purpose of the identified objects and explain the properties of the materials used to suit the purpose through Sketchbook.<br><br>3. **KWL reflection**<br>• Students update the KWL to reflect their learning, especially on their thoughts on fairness of experiment. |

We analyse the teacher enactment of the lessons using the dimensions of general performance with her pedagogical orientations, the ways she used technology in classroom (Ottenbreit-Leftwich et al., 2012) and the patterns of interaction with the students. Her pedagogical orientation was examined through analyzing her classroom management, instruction of key concepts and her responses to students' questions and activities. Teacher and students verbal behavior were mainly analyzed and compared (King, 1999). The ways in which she integrated the technology in her lessons were discussed and assessed to evaluate her competencies on the use of mobile technology in the class. The data analysis was proposed to further reveal teachers' pedagogical orientations toward the traditional belief (more teacher-guided activities) or constructivist belief (more student-centered activities) on the mobile technology in their lessons (An & Reigeluth, 2012). To visualize the details of teacher enactment of lessons in real class, we also explored her 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 selected lesson episode (Gillies, 2006; Ge & Land, 2004), and by examining the contents and recipients of these questions and scaffolds, this intended to present her patterns of interacting with their students (Chiu, 2004). To verify the student achievement, their learning artifacts in MyDesk were presented and analyzed. The two researchers examined the data individually and then collaboratively in order to reach consensus regarding the identification and description of the teacher's pedagogical orientations and her detailed performance in the teaching practices, as well as students' quality of learning artifacts. The research team helped to check any discrepancies, and made the final decision for the alignment of the coding. Thus, there was no disagreement in the following description and discussion of findings.

## 6. Findings

### *6.1 Pedagogical Orientation*

Teacher's belief was identified as the most important influence on what they practice in the classroom (Carlson, 1994). The analysis of teacher pedagogical orientation provides a window into teachers' personal beliefs that influence the enactment of M5ESC and the impact of this on the students' responses. As a leading teacher, 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 compared to her previous class. In M5ESC, 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. Students had more opportunities to discuss with Jodie and their partners in the collaborative activities as Jodie involved frequently in students' peer discussion. For students' experiment, she frequently interacted with students and provided students with scaffolds they required. She focused more on detecting knowledge understanding than reviewing learning artifacts. 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, and conducting group discussions) to guide and assist students' learning and inquiry, and focused more on developing crucial learning skills instead of emphasizing on remembering and understanding the subject knowledge (Wildy & Wallace,1995).

### *6.2 Technology Integration*

Table 2 presents the strategies in which Jodie used the technology or technology-related learning artifacts in the instruction of materials in the mobilized 5E science curriculum. We discriminated the ways she used technology as either teacher-guided strategies (Bielefeldt, 2012) or student-centered strategies (Kerawalla, Petrou, & Scanlon, 2013). As we can see in Table 2, more student-centered strategies of technology integration were conducted in Jodie's class, this further reflected her pedagogical orientation on the use of technology in the class. The findings were aligned with the analysis of the pedagogical orientations discussed in the previous section.

Table 2. The ways of the technology integration into the class

| Ways of the use of technology | Teacher-guided | Student-centered |
|---|---|---|
| • **Monitoring the progress** | √ | |
| • **Evaluation tool** | √ | |
| • **Identifying misconceptions** | √ | |
| • **Conducting collaborative work** | | √ |
| • **Guiding students' discussion and thinking** | | √ |
| • **Reflection tool** | | √ |
| • **Comparison tool** | | √ |
| • **Supporting collaborative work** | | √ |

In the class of "Exploring Materials", Jodie looked through students' KWL responses and presented the typical work in different quality levels with asking series of questions. She used Socrative.Com (a mobile software supporting presenting multi-choice questions, and reviewing students' responses) 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.Com. When students were working together, she was involved in several groups for providing scaffolds 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.

### *6.3 Teacher-Student Interaction*

Mediated-learning was a way of interaction between the teacher and students. 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 challenging student ideas (Weinberger & Fisher, 2006). In Jodie's class, she provided various scaffolds for students and was frequently involved in students' activities in her class. Specifically, Jodie was involved frequently in students' work and tended to provide appropriate scripts and prompts for the students to find the solutions by themselves. Thus, a series of questions were posed in her classes for investigating students' knowledge and identifying misconceptions. There were different levels of interactions existed Jodie's class: teacher-class level: 60 and teacher-student level: 52. As we observed, when she would introduce or explain the key concepts of the materials, she posed a series of exploratory questions (n=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 identifying their misconceptions or probing their current understanding. The findings reflected 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 excerpts:

*Jodie: Are you trying to say it is not flexible? if it is not flexible ,what will 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?*

It was found that Jodie provided various scripts for scaffolding students' hands-on experiment (n=14) and demonstration (n=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.*

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. This was specially benefited for the low ability students' completing the task. When students were doing their activities, Jodie mostly detected their problems and was involved in their discussion with providing prompts (4) and challenging their ideas (6). Most students were engaged in their activities and acted the appropriate role in the task. Thus, Jodie could successfully act as a guide, facilitator and mentor in students' activities, which led to students' active participation in hands-on activities and other learning activities.

### *6.4 Student learning artifacts*

Guided by the teacher's instruction, an analysis of the learning actifactes created by students indicated that students benefited a lot in conceptual understanding from M5ESC. Based on the analysis of students' learning artifacts in MyDesk, we found that students performed actively in MapIT, KWL and Skecthbook activities. Take "Exploring Materials" as example, students were required to construct concept maps of material classification using MapIT at first. It was found that most concept maps could present the correct understanding of materials classification. Notably, there were a number of high quality concept maps which described the material classification and the properties. See the following typical high quality concept maps constructed by students.

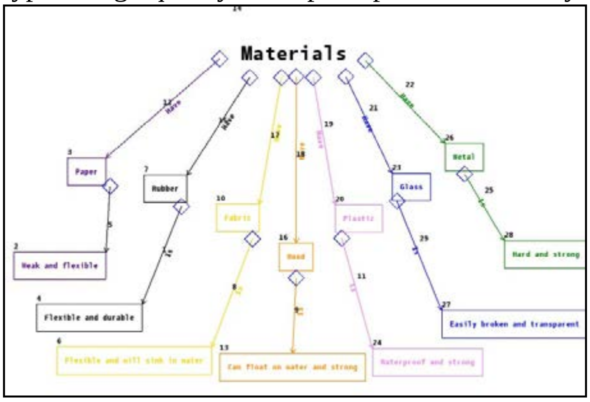


Figure 2a. Concept map A

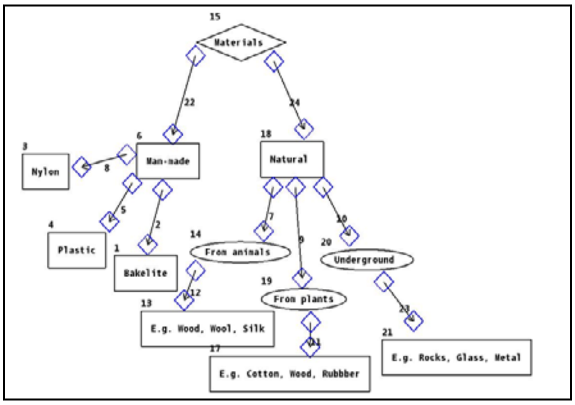


Figure 2b. Concept map B

Students' positive KWL responses on "what I know and what I have learnt" suggested they had learnt more about materials compared to their understanding at the beginning stage of the lessons. They also raised multiple questions at "what I want to know", which reflected their desire and interests in investigating the new knowledge. We selected some excerpts from KWL "What I know".

- *Some materials are man -made and some materials are natural.*
- *There are hard, soft, strong, weak, flexible stiff waterproof and absorbent materials.*
- *Metal is a good conductor of heat and electricity.*
- *I know that a thing might be made of many materials.*

Reviewing student' Sketchbook work which referred to identifying objects and explaining the properties of the materials, we found that most students could relate their new knowledge with their daily life experiences. This indicated that students could apply their knowledge in the new context and their improvement on their knowledge at the cognitive levels. See the following artifacts we selected:


Figure 3a. Artifact A


Figure 3b. Artifact B


Figure 3c. Artifact C

## 7. Conclusion

Regarding to the purpose of TPD for technology-facilitated curriculum, Diaconu et al., (2012) stated that teacher content knowledge and pedagogical practice was the impetus for building a strong community of teachers to be readiness of curriculum. He suggested that more evidence is required to establish the link between professional development and the teacher practices that act as mediating factors between the professional development and the instruction experienced by the students. Thus, in this study, we connect the research of TPD with teachers' teaching practices and students' performance. This helps us gain deep insight into teacher changes. From our data analysis, we recognized that long-term and school-based TPD for M5ESC could change teachers' pedagogical orientation on the conducting students' activities, asking questions and the patterns of interacting with students and the technology use in the class. The pedagogical practices would gradually move toward constructivist strategies. The results showed that there were mutual relationships among TPD, curriculum implementation and teacher growth. First, through observing teacher and student performance, TPD will consider some aspects further that we might not emphasized in the regular working sessions, such as teachers' knowledge of technology integration, and the ways for designing student-centered activities. Second, the curriculum design will be modified to be more elaborated based on our data analysis of students' performance. Third, teacher understanding of constructivist belief and pedagogical practice on the technology integration in class will be gradually transformed over time with the efforts of TPD and their enactment of M5ESC. In the further work, we will focus more on the relationship between teacher changes and the development of TPD. More studies will be conducted for identifying teacher differences of the enactment of the same lesson plan of M5ESC. The work will be used to inform the scaling of M5ESC to another grade level in the school as well as to other schools.

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