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Fostering Pre-service Science Teachers' Technological Pedagogical Content Knowledge of Mobile Laboratory Learning in Science

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Abstract: The framework of technology pedagogical and content knowledge (TPACK) is currently considered as essential qualities of knowledge for highly qualified teachers in the 21st century education. This knowledge framework has been suggested by researchers to be helpful in preparing literate pre-service teachers in the use of digital technology in their classroom teaching practices of specific subject contents. As such, the researchers have implemented the framework for designing a module of the pedagogy of Mobile Laboratory Learning in Science (MLLS) for pre-service science teachers. The purpose of this study was to examine an efficacy of the MLLS for enhancing pre-service science teachers' TPACK. The study participants were 119 pre-service science teachers in general science teacher education program at a Rajabhat university of Thailand, and they were assigned to participate with the module in four weeks. The preliminary results showed that the pre-service science teachers have improved their conceptions of TPACK of mobile laboratory learning in science to higher level after interacting with the MLLS module.

Keywords: TPACK, mobile learning, science laboratory, mobile experimentation, pre-service teacher

1. Introduction

Mobile devices are recognized as an emerging technology with the potential to facilitate teaching and learning strategies that exploit individual learners' context (Jeng et al., 2010). Nowadays, the use of mobile devices in education, as mobile learning, is popular educational activity that many researchers have implemented in many subject areas for improving the effectiveness of instruction. Mobile learning makes sense only when the technology in use is fully mobile and when the users of the technology are also mobile while they learn. These observations emphasize the mobility of learning and the significance of the term mobile learning (El-Hussein, M. O. M., & Cronje, J.C., 2010). Mobile technology offers a plethora of features and benefits that enable it to break the educational system wide open, engaging students in new ways and making educational experiences more meaningful. It offers flexibility in when the learning take place, personalized content, teaches relevant skills for the future. Mobile technologies offer a new paradigm in connectivity, communication, and collaboration in our everyday lives. It is anywhere, anytime learning indeed (McQuiggan et al., 2015). In context of science education, this has led to several research initiatives that investigate the potential of the educational paradigm shift from the traditional science teaching approaches to mobile learning in science. Currently, researchers in science education community have concentrated on investigating effective ways to facilitate science learning in authentic context with the support of mobile technology.

Mobile learning in science seems to be a pedagogic way to deliver the authenticity of scientific phenomena into science teaching and learning, both formal and informal contexts. More precisely, mobile learning can (a) engage students in experiential and situated learning without place, time and device restrictions, (b) enable students to continue learning activities, initiated inside the traditional classroom, outside the classroom through their constant and contextual interaction and communication with their classmates and/or their tutors, (c) support on-demand access to educational resources regardless of students' commitments, (d) allow for new skills or knowledge to be immediately applied and (e) extend traditional teacher-led classroom scenario with informal learning activities performed outside the classroom (Gomez et al., 2014). With the advancement of mobile technology, learning in real-world context, outside the classroom, is no longer a problem and learning combined with authentic contexts becomes easier for science-based education. However, a challenge for mobile learning in science related to teachers' adoption of mobile technologies in their science class emerged from the fact that they were not prepared effectively in investigating the affordances of mobile technologies for their pedagogy and the content they teach to make informed decisions (Kukulska-Hulme et al., 2008).

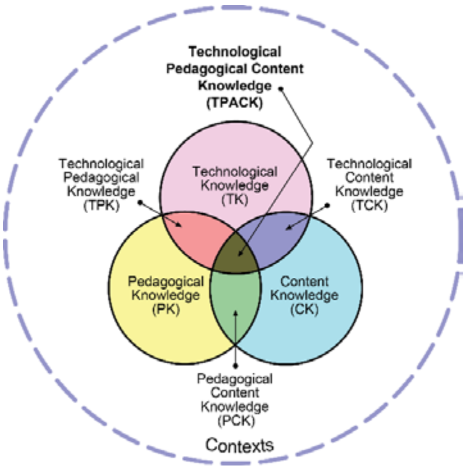
The big challenge for mobile learning in science related to teachers' adoption of mobile technologies in their science class emerged from the fact that they were not prepared effectively in investigating the affordances of mobile technologies for their pedagogy and the content they teach to make informed decisions (Kukulska-Hulme et al., 2008). We believed that a major obstacle of science teachers for using mobile technology in the classroom is the lack of sufficient knowledge and skills of how to utilize it pedagogically into the science class. To overcome this obstacle, Smarkola (2008) has suggested training preservice teachers in educational technology during their initial teacher education. To achieve that, their knowledge of how to use mobile technology in science teaching and learning is very important for gaining high quality teaching competencies in science. Srisawasdi (2014) stated that not only all students need a more robust process of technology-enhanced science learning, but teachers also need to be educated and prepared for gaining high quality teaching competencies by integrating digital technologies, such as mobile devices, into their classroom teaching practice.

Preparing preservice teachers for digital technology integration is a complex job given the fast-changing nature of digital technology, such as mobile devices, and the multiple sources of knowledge which need to be synthesized. Meaningful use of digital technology in the classroom requires the teachers to integrate technological affordances with pedagogical approaches for the specific subject matter to be taught (Jonassen et al., 2008; Mishra & Khoeler, 2006) To be an technology-integrating teacher means going beyond technology skills, and developing an understanding of the complex relationships between pedagogy, content and technology (Hughes, 2005; Keating & Evans, 2001; Lundeberg, Bergland, Klyczek & Hoffman, 2003; Margerum-Leys & Marx, 2002; Niess, 2005; Zhao, 2003). Hence, a teacher preparation program should provide students with the knowledge, skills, and experience needed to integrate technology effectively in their future practice, considering the interactions between pedagogy, content and technology. This integrated form of contextualized knowledge has been recently referred to as technological pedagogical and content knowledge, shortly called TPACK (Mishra & Khoeler, 2006; Thompson & Mishra, 2007). TPACK is currently considered as possessing the essential qualities of knowledge for highly qualified teachers in the 21st century (Srisawasdi, 2014).The TPACK framework stresses the importance of the interactions between these bodies of knowledge.These include pedagogical content knowledge PCK) as addressed by Shulman (1987), technological content knowledge (TCK) referring to how ICT and content influence each other, technological pedagogical knowledge (TPK) addressing how pedagogies change while using technology, and technological pedagogical content knowledge (TPACK), which is the knowledge that emerges from interactions among the three knowledge domains (Koehler & Mishra, 2008). The TPACK framework has been used to re-design teacher preparation programs and teacher development workshops (i.e. Niess, 2005; Niess, 2007; Niess, Suharwoto, Lee, & Sadri, 2006; Shoffner, 2007; Burns, 2007). Special emphasis has been given to incorporating technology design projects as avenues to help teachers develop connections between TK, PK, and CK (i.e. Niess, 2005; Mishra & Koehler, 2006; Srisawasdi, 2014). TPACK may new directions for teacher educators in solving the problems associated with infusing ICT into classroom teaching practice and learning process (Chai et al., 2011 cited in Srisawasdi, 2012). However, mobile learning is especially under-theorized in teacher education (Kearney & Maher, 2013), despite the need to inform teachers of the value of mobile technologies and how to integrate them effectively into their classes (Schuck, Aubusson, Kearney, & Burden, 2013). Moreover, teacher support and teacher training for TPACK in mobile learning in science have been the least explored topics in science teacher education research. The goal of this study was to explore effect of TPACK-oriented learning module for pre-service science teacher on their TPACK of mobile laboratory learning in science. This paper presents an investigative result of the transformation of TPACK in mobile laboratory learning in science in the pre-service science teachers.

2. Literature Review

2.1. Technological Pedagogical and Content Knowledge (TPACK)

In recent years, many researchers in the field of educational technology have been focused on the role of teacher knowledge on technology integration)Hughes, 2005; Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006; Niess, 2005(. The term TPACK)also known as TPCK; Koehler & Mishra, 2005(has emerged as a knowledge base needed by teachers to incorporate technology into their teaching. Technological pedagogical and content knowledge)TPCK(was introduced to the educational research field as a theoretical framework for understanding teacher knowledge required for effective technology integration)Mishra and Koehler, 2006(. The TPCK framework acronym was renamed TPACK for purpose of making it easier to remember and to form a more integrated whole for the three kinds of knowledge addressed: technology, pedagogy, and content)Thompson and Mishra, 2007(. This framework builds on Shulman's)1986(construct of pedagogical content knowledge)PCK(to include technology knowledge.



<u>Figure 1</u>. Technological Pedagogical and Content Knowledge)TPACK(framework)http://tpack.org(.

TPACK was first proposed by Mishra and Koehler)2006(to describe an integrated connection between content knowledge, pedagogical knowledge, and technological knowledge. The framework illustrates essential knowledge of how teacher could integrate technological tools into their teaching of specific content in their school practice)Srisawasdi, 2012(. It is most commonly represented in a drawing of Venn diagram with three overlapping circles of knowledge. The TPACK diagram includes three core categories of knowledge such as the process and practices or methods of teaching and learning called pedagogical knowledge)PK(, the knowledge about the actual subject matter that is to be learned or taught called content knowledge)CK(, and the knowledge about standard technologies and the skills required to operate particular technologies called technological knowledge)TK(. The Mishra and Koehler)2006('s framework also process that these three core types of knowledge results in four additional types of knowledge including the knowledge about particular teaching practice that appropriately fit the nature of specific subject content called pedagogical content knowledge)PCK(, the knowledge about the existence, component and capabilities of standard technologies that could be appropriately used to particularly support in the processes and practices or methods and learning called technological pedagogical knowledge)TPK(, the knowledge about the manner which knowledge of actual subject matter could be manipulated into appropriate representations by application of standard technologies called technological content knowledge)TCK(, and knowledge about the manner which the transactional relationship between knowledge about content)C(, pedagogy)P(, and technology)T(was dynamic in order to develop appropriate, context-specific, strategies, and representations for better learning of content knowledge called technological pedagogical content knowledge)TPACK(.

Seven components)see Figure 1(are included in the TPACK framework. They are defined as:

1. Technology knowledge) TK(: Knowledge about various technologies, ranging from low-tech technologies, such as pencil and paper, to digital technologies, such as the Internet, digital video, interactive whiteboards, and software programs.
2. Content knowledge)CK(: Knowledge about the actual subject matter that teachers must know about to teach.
3. Pedagogical knowledge) PK(: Knowledge about the methods and processes of teaching such as classroom management, assessment, lesson plan development, and student learning.
4. Pedagogical content knowledge) PCK(: Knowledge that deals with the teaching process) Shulman, 1986(. Pedagogical content knowledge is different for various content areas, as it blends both content and pedagogy with the goal to develop better teaching practices in the content areas.
5. Technological content knowledge) TCK(: Knowledge of how technology can create new representations for specific content.
6. Technological pedagogical knowledge) TPK(: Knowledge of how various technologies can be used in teaching.
7. Technological pedagogical content knowledge)TPACK(: Knowledge required by teachers for integrating technology into their teaching in any content area. Teachers, who have TPACK, act with an intuitive understanding of the complex interplay between the three basic components of knowledge)CK, PK, TK(.

For the science education community, the efforts of current science education reforms expect science teachers to integrate digital technology and inquiry-based teaching into their instruction (Srisawasdi, 2014). In this light for science teacher education, both pre-service and in-service science teachers are targeted to improve teaching proficiency based on the implementation of TPACK in many kinds of instructional intervention, i.e. coursework, training, and workshop, by teacher education researchers and educators (Srisawasdi & Panjaburee, 2014). As such, it is clearly that the development of science teacher education program based on TPACK framework is an important for preparing both pre-service and in-service science teacher to gaining high quality teaching competencies by integrating technologies into their science teaching practice.

2.2. Mobile Learning and Teacher Education

Mobile devices have become attractive learning devices for education, and teachers' adoption of mobile technologies have been recognized as a potential way for transforming traditional teaching into student-centered approach. Because of the rapid growth of mobile technologies as learning devices and its features and functions supported active learning, teacher education programs need to implement theoretically and pedagogically sound mobile learning initiatives in order to effectively integrate mobile devices for facilitating students' learning process (Newhouse et al., 2006). Passey and Zozimo (2015) suggested that when using handheld devices there is a need for teachers to consider how the learning environment might be expanded beyond the classroom, due to the portability features of the devices. Currently, researchers and teacher educators have showed an increasing interest in the integration of mobile technologies into teacher education in both pre-service and in-service teacher contexts (Baran, 2014). With being more ubiquitous of mobile technologies, the pedagogical affordances of mobile devices will continually be explored in teaching contexts. Especially, mobile learning is recognized by teacher education researchers as a beneficial approach in extending both pre-service and in-service teachers' learning experiences and enhancing their mobile technology integration skills (Baran, 2014). For example, teacher education events need to identify the many applications (Apps) that can meet specific subject and topic needs, and teachers also need to be aware of both the benefits and limitations of handheld devices for teaching and learning in both formal and informal education. Baran (2014) mentioned that there are two methods for integrating mobile learning into teacher education contexts; (a) teacher training about mobile learning, where teachers learn how to integrate mobile tools into their classrooms, and (b) teacher training with mobile learning, where teachers interact to learn with mobile technology.

3. Methods

3.1. Study Participants

A total of 119 pre-service science teachers, 4th year students, enrolled in the Classroom Management and Learning Environment for Science Learning course at General Science Program, Faculty of Education, Roi Et Rajabhat University, Thailand, participated in this study. All of them came from four sections of the enrolled course. They were 93 females and 26 males and they age between 21-22 years old. All of them did have satisfactory basic information and communication technology (ICT) skills but they had not any experience with using digital technology and mobile devices for science experiments and science instruction before.

3.2. Detail of the Mobile Laboratory Learning in Science (MLLS) module

This research employed a quasi-experimental research design that involved two phase of data collection – pre and post module. The participants were introduced into a module of Mobile Laboratory Learning in Science (MLLS) for pre-service science teacher. The MLLS module consisted of 4 three-hour weekly lecture and practices, and divided into four lessons, as shows in Table 1.

Table 1: Details of the MLLS module for pre-service science teacher preparation based on TPACK

Lesson	Week	Domain	Learning strategy	Knowledge object
1	1	Introduction to microcomputer-based laboratory (MBL), a digital technology tool in science learning	Interactive lecture and demonstration	TK
2	2	Pedagogy of inquiry-based learning in science with the support of MBL	Interactive lecture and demonstration	TCK, TPK, TPACK
3	3	Hands-on practical work with mobile MBL	Hands-on practical work	TCK, TPK, TPACK
4	4	Designing mobile MBL learning activity in science	Hands-on practical work	TPACK

For the MLLS module, the first lesson is an introduction of the sensor-based digital technology tool, called microcomputer-based laboratory (MBL), in science learning. In this lesson, the instructor (the first author) introduced the history of MBL in science education and presented the tool and its information in the class. Moreover, the instructor also demonstrated how to use the tool in school science laboratory. Figure 2 illustrates the introduction of MBL in science learning class.

Figure 2. An Illustration of the first lesson class, an introduction of MBL for preservice science teachers

In the second lesson, the instructor introduced them the pedagogy of inquiry-based learning in science in both instructional strategies, i.e. learning cycle-oriented and openness-oriented approach (Srisawasdi, 2016). Then, they were presented to a mini lesson on how to use MBL as an inquiry tool in the learning process of science. In addition, the instructor also showed the pedagogic case for implementing technology-enhanced science learning with the support of sensor-based MBL, as shows in Figure 3.

Figure 3. An Illustration of the pre-service science teachers' practice in class using sensor-based MBL in the second lesson

For the hands-on practical work with mobile MBL in the third lesson, the instructor assigned the pre-service teachers to conduct a scientific inquiry with mobile MBL outside the classroom. The mobile MBL-based scientific inquiry was focused on the investigation of water quality of various resources within the university. They were assigned to conduct the investigation in small groups by using smartphone and MBL connected via Bluetooth. Figure 4 illustrates the pre-service science teachers with conducting the water quality experiment with mobile laboratory.

Figure 4. An Illustration of the pre-service science teachers' hands-on practical work in outdoor sites using mobile sensor-based MBL in the third lesson

In the last lesson of this module, all small groups of the pre-service science teachers have been assigned to collaboratively design their own learning activity of mobile laboratory learning in science. Before the collaborative activity to design the learning activity, the instructor presented a summary of the science learning activity of water quality experiments with the support of mobile MBL and then digested the TPACK framework and components regarding the water quality learning activity. After, they were encouraged to brainstorming and then independently design a science learning activity with utilizing the mobile MBL as inquiry tool. Figure 5 illustrates the pre-service science teachers' presentation of teaching idea regarding the implementation of mobile MBL-based inquiry learning in science.

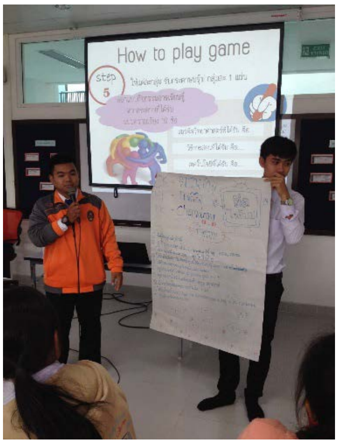


Figure 5. An Illustration of the pre-service science teachers' presentation of their teaching ideas with the support of mobile MBL approach

3.3. Data Collection and Analysis

Before the first and after the last week of this module, the study participants were asked to complete a series of open-ended question regarding TPACK in mobile laboratory learning in science for 40 minutes as pretest and posttest. In this study, the researchers focused on only four components regarding technology-oriented TPACK constructs, i.e. TK, TPK, TCK, and TPACK. This questionnaire was validated the construct and communication validity by four experts who hold Ph.D. in science and technology education, and educational technology. When assessing each aspect of TPACK for mobile laboratory learning in science, the respondents (pre-service science teacher)' views were categorized in four levels (Informed, Mixed, Naïve, and Unclear) adapted from Bartos and Lederman (2014)'s idea of teaching conception analysis. For this study, if by contrast, a respondent provides a response consistent across the entire questionnaire that wholly congruent with the target response for a given aspect of TPACK, they were labeled as "*Informed*."

If by contrast, a response is either only partially explicated, and thus not totally consistent with the targeted response regarding TPACK, or if a contradiction in the response is evident, a score of "*Mixed*" is given. A response that is contradictory to accept views of specific aspect of TPACK under examination is scored as "*Naïve*." Lastly, for scores that are incomprehensible, intelligible, or that, in total, indicate no relation to the particular aspect, a categorization of "*Unclear*" is assigned (Lederman et al., 2014). In regard to concerns about the open-ended format of relationship between content knowledge, pedagogy knowledge, and technology knowledge, any essay-type questions require additional effort by the researchers to discern the level of TPACK of the preservice science teachers. To identify general trends in the preservice science teachers' TPACK at the module, this type of open-ended instrument is typically utilized, and can be facilitated by the four-tired assessment scale. The format also best serves the overarching intent of the instrument, which is to create profile of preservice science teachers' TPACK.

4. Results and Discussions

According to explore the effect of MLLS module on pre-service science teachers' partial TPACK components such as TK, TPK, TCK, and TPACK, the results shows in Table 2.

Table 2: Percentage of the pre-service science teachers' TK, TPK, TCK, and TPACK categorized as holding unclear, naïve, mixed, and informed views of TPACK

N=119 % of Pre-service Science Teachers	Technological Knowledge (TK)		Technological Pedagogical Knowledge (TPK)		Technological Content Knowledge (TCK)		Technological Pedagogical Content Knowledge (TPACK)	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Unclear	0.00	0.00	0.84	0.00	0.84	0.00	1.68	0.00
Naïve	19.33	10.08	47.90	34.45	72.27	52.10	70.59	52.10
Mixed	78.99	88.24	51.26	63.03	26.89	46.22	26.05	46.22
Informed	1.68	1.68	0.00	2.52	0.00	1.68	1.68	1.68

Individual profiles were developed based on holistic analysis of TPACK responses. Results indicated that the majority of preservice science teachers (a) were *Naïve* view in their conception of TPACK in both prior and finish to instruction, (b) increase their understanding from *Naïve* to *Mixed* such as Technological Knowledge (TK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Technological Pedagogical Content Knowledge (TPACK) and (c) increase their understanding to *Informed* degree for Technological Pedagogical Knowledge (TPK), and Technological Content Knowledge (TCK).

In summary, the results of this preliminary study provided evidences that preservice science teachers' TK, TPK, TCK, and TPACK has been fostered during their interacting with the MLLS module for preservice science teachers. This finding is consistent with Jimoyiannis (2010), Jang & Chen (2010), Srisawasdi (2012), Srisawasdi (2014), and Srisawasdi & Panjaburee (2014) that implementation well-designed coursework could foster preservice or in-service science teachers' essential knowledge of TPACK.

5. Conclusion

This study reported a result of an implementation of TPACK-oriented pedagogical module of mobile laboratory learning in science for preservice science teachers and the findings revealed the preservice science teachers have been fostered their TK, TPK, TCK, and TPACK on the pedagogy of mobile laboratory learning in science. Thus, this implies the possibility of enhancing preservice science teachers' TPACK of mobile learning in science and it could be an effective way to develop their essential knowledge of technology-enhanced learning in science to address the 21st century education.

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