Preparing pre-service teachers to integrate mobile technology into science laboratory learning: an evaluation of technology-integrated pedagogy module

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Abstract: With the rapid advance and popularity of wireless communication and mobile technologies, pedagogy of mobile and ubiquitous learning has become more important and teachers’ technology pedagogical and content knowledge (TPACK) within mobile learning context is more emphasised in pre-service teachers’ education. As such, pre-service science teachers’ TPACK of mobile learning has been recommended as an essential framework for preparing literate pre-service science teachers in the use of mobile technology in teaching practices. Therefore, the researchers have implemented the framework for designing a technology-integrated pedagogy module, called Mobile Laboratory Learning in Science (MLLS). The purpose of this study was to evaluate an effect of MLLS module in improving 119 Thai pre-service science teachers’ TPACK. The preliminary results showed that the pre-service science teachers have better level of technological knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and TPACK of mobile laboratory learning in science after interacting with the MLLS.
Keywords: TPACK; mobile learning; science laboratory; ubiquitous technology; pre-service teacher.

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1 Introduction

Increasingly in the past decade, mobile technologies, such as smartphones and tablet computers, have been applied to educational settings in order to improve the quality of education and the process of learning mediated by mobile – portable and networked – technologies have been concerned worldwide among educational researchers, developers, and practitioners. Mobile devices (or m-devices) are recognised as an emerging instructional tool with the potential to facilitate teaching and learning strategies that exploit individual learners’ context (Jeng and Chen, 2010). Nowadays, the use of mobile devices in education, as mobile learning or m-learning, is popular educational activity that many researchers have implemented in many subject areas for improving the effectiveness of instruction in the kind of “anytime, anywhere” situations. In addition, 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, and it is anywhere, anytime
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learning indeed (El-Hussein and Cronje, 2010; McQuiggan et al., 2015). According to Baran (2014), mobile learning emphasises mobility, access, immediacy, situativity, ubiquity, convenience, and contextuality, and it includes the characteristics of mobility in physical, conceptual, and social spaces. As such, the learning with 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 the mobility of learning makes educational experiences more meaningful. 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 (Srisawasdi et al., 2016).

Mobile and ubiquitous 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). To enhance the learning in science, mobile and ubiquitous learning have been concerned to implement in context of museums, outdoor field, classrooms, or laboratory (Hwang and Tsai, 2011). 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. For example, Chu et al. (2010) and Hwang et al. (2011) developed a grid-based mind tool displayed on mobile device and employed as an instructional tool to guide elementary school students to observe the features of plants in a natural science course. In another study, Hung et al. (2010) conducted a series of mobile learning activities for ecology observations and data collection in a wetland in southern Taiwan. However, a challenge for mobile learning in specific subject related to teachers’ adoption of mobile technologies in their 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 and Shield, 2008). In addition, researchers 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 utilise it pedagogically into the science class. To overcome this obstacle, Smarkola (2008) has suggested training pre-service 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 pre-service 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 synthesised. 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 and Koehler, 2006). A technology-integrating teacher means going beyond technology skills and developing an understanding of the complex relationships between pedagogy, content and technology (Hughes, 2005; Keating and Evans, 2001; Lundeberg et al., 2003; Margerum-Leys and 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 contextualised knowledge has been recently referred to as technological pedagogical and content knowledge, shortly called TPACK (Mishra and Koehler, 2006; Thompson and 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 (Coehler and Mishra, 2008). The TPACK framework has been used to re-design teacher preparation programs and teacher development workshops (i.e., Niess, 2005; Niess et al., 2009; Niess et al., 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 and Koehler, 2006; Srisawasdi, 2014). TPACK may provide new directions for teacher educators in solving the problems associated with infusing ICT into classroom teaching practice and learning process (Srisawasdi, 2012). However, mobile learning is especially under-theorised in teacher education (Kearney and Maher, 2013), despite the need to inform teachers of the value of mobile technologies and how to integrate them effectively into their classes (Schuck et al., 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. The purpose of this study was to assess the change in TPACK of mobile laboratory learning in science, and 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 and Mishra, 2005, 2008; Mishra and Koehler, 2006; Niess, 2005). The term
TPACK (also known as TPCK; Koehler and 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.

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 (TPCK): Knowledge required by teachers for integrating technology into their teaching in any content area. Teachers, who have TPCK, act with an intuitive understanding of the complex interplay between the three basic components of knowledge (CK, PK, TK).

Figure 1  Technological pedagogical and content knowledge (TPACK) framework (http://tpack.org)

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 and 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 has been recognised as a potential way for transforming traditional teaching into student-centred approach. As such, the learning with mobile devices represents an innovative teaching opportunity with a new set of technologies for teacher educators to consider in their courses and field-based experiences. 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). Moreover, the next generation of teacher graduates will need to receive hands-on and practicum-based experience with using mobile devices and applications for teaching in different learning environments. 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 recognised 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 Context of the study

With the advancement of educational technology and a wide range of digital tools in science education (e.g. digital probeware and sensors, mobile devices and application, modelling tools, simulation and animation, virtual and augmented reality, digital and serious game, web-based learning system), these tools should be situated in a flexible framework of knowledge of content, pedagogy, and technology.

Due to the demanding use of mobile technology to support inquiry-based teaching and learning in science, teachers’ knowledge of science concept, pedagogy, and technology and their interaction is necessary for successful integration of mobile technology into the science classroom. As such, this paper proposes an integrative framework of essential knowledge for using mobile/wireless MBL in inquiry-based science learning for promoting the learning of science concept as presented in Figure 2.
The TPACK framework proposes seven distinct categories of essential knowledge for teachers. However, for the purposes of this paper, only the four categories associated with technology (i.e., TK, TCK, TPK, and TPCK) will be considered, as shown in Figure 2. All four categories are strongly interrelated due to their common denominator. In this study, TK refers to technical understanding and skills required to operate wireless microcomputer-based laboratory (wireless MBL) instruments and their software (e.g., setup and use of built-in sensors to detect and record data). While TCK refers to technological competencies or knowledge of technology tools and representations specific to particular content of science, which requires technological affordances of wireless MBL for transforming the content (e.g., use of data collection and analysis tools like digital probes or sensors and spreadsheets), TPK focuses on instructional competencies that allow teachers to enhance science learning while incorporating wireless MBL in the enactment of the curriculum (e.g., use of data logger and digital probe to motivate learners and actively engage them into scientific inquiry process). Finally, TPCK represents the set of instructional competences regarding the use of wireless MBL to support content-specific pedagogical strategies (e.g., the use of wireless MBL to facilitate inquiry-based science learning in outdoor site).

4 Methods

4.1 Study participants

This study employed a quasi-experimental research design that involved two phases of data collection – pre- and post-module. A total of 119 pre-service science teachers, the fourth-year students, enrolled in the classroom management and learning environment for
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Science learning course at General Science Education 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 (78%) females and 26 males (22%) and they age between 21 and 22 years old. All of them did have satisfactory basic information and communication technology skills but they had not any experience with using digital technology and mobile devices for science experiments and science instruction before.

4.2 Detail of the mobile laboratory learning in science (MLLS) 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 three phases, as shows in Table 1. The participants are involved in the three phases of instruction with the instructor (the second author):

1 Learning with technology phase (P1) – four hours of interactive lecture demonstration and discussion on what is microcomputer-based laboratory (MBL) and how to operate the MBL using a specific software.

2 Enacting with technology through pedagogy phase (P2) – eight hours of in-depth study of technology-integrated pedagogy of mobile MBL-enhanced inquiry learning in science through interactive lecture demonstration in classroom, and hands-on practical enactment of full science inquiry in field locations.

3 Transferring the technology-pedagogy interaction phase (P3) – four hours of designing, presenting, and discussing on their own science lesson focused mobile MBL-enhanced inquiry learning activity.

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

<table>
<thead>
<tr>
<th>Phase</th>
<th>Week</th>
<th>Topic</th>
<th>Learning strategy</th>
<th>Knowledge domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>1</td>
<td>Introduction to microcomputer-based laboratory (MBL), a digital technology tool in science learning</td>
<td>Interactive lecture and demonstration</td>
<td>TK</td>
</tr>
<tr>
<td>P2</td>
<td>2</td>
<td>Pedagogy of inquiry-based learning in science with the support of MBL</td>
<td>Interactive lecture and demonstration</td>
<td>TCK, TPK, TPACK</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Inquiry-based hands-on practical work with wireless MBL</td>
<td>Hands-on practical work</td>
<td>TCK, TPK, TPACK</td>
</tr>
<tr>
<td>P3</td>
<td>4</td>
<td>Designing mobile MBL learning activity in science</td>
<td>Hands-on practical work</td>
<td>TPACK</td>
</tr>
</tbody>
</table>

For the MLLS module, the first week 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 3 illustrates the introduction of MBL in science learning class.
In the second week, 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 4.

For the hands-on practical work with mobile MBL in the third week, 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 5 illustrates the pre-service science teachers with conducting the water quality experiment with mobile laboratory.
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In the last week 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

Figure 5 An illustration of the pre-service science teachers’ hands-on practical work in outdoor sites using mobile sensor-based MBL in the third lesson

Figure 6 An illustration of the pre-service science teachers’ presentation of their teaching ideas with the support of mobile MBL approach
with utilising the mobile MBL as inquiry tool. Figure 6 illustrates the pre-service science teachers’ presentation of teaching idea regarding the implementation of mobile MBL-based inquiry learning in science.

### 4.3 Data collection and analysis

Before the first and after the last week of this module, the study participants were asked to complete a 7-items open-ended question regarding TPACK in mobile laboratory learning in science for 40 minutes as pre-test and post-test. In this study, the researchers focused on only four components regarding technology-oriented TPACK constructs, i.e. TK, TPK, TCK, and TPCK. This questionnaire was validated the construct and communication validity by four experts who hold Ph.D. in science and technology education, and educational technology. A scoring scheme was developed by the researchers and five raters were given extensive training. The responses to each test item were coded by three raters independently, with coding discrepancies discussed between all raters until 100% agreement was reached for each participant’s response across the four targeted aspects. Thus, in terms of objectivity and reliability, the test construction can be considered successful. When assessing TK, TPK, TCK, and TPCK for mobile laboratory learning in science, the respondents (pre-service science teacher)’ views were categorised 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 labelled 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 categorisation 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 pre-service science teachers. To identify general trends in the pre-service science teachers’ TPACK at the module, this type of open-ended instrument is typically utilised, 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 pre-service science teachers’ TPACK.

### 5 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 TPCK, the results shows in Table 2.
Individual profiles were developed based on holistic analysis of TPACK responses. Results indicated that most of pre-service science teachers’ TK (a) were Mixed level in both prior and finish to instruction, and (b) increase their understanding from Naïve to Mixed level. For TPK and TCK, the results indicated that the majority of them (a) were Mixed and Naïve level, respectively, in both prior and finish to instruction, and (b) increase their TPK and TCK from Unclear and Naïve to Mixed and Informed level. Finally, the results also indicated that most of pre-service science teachers’ TPCK (a) were Naïve level in both prior and finish to instruction, and (b) increase their understanding from Unclear and Naïve to Mixed level. More details regarding the pre-service science teachers’ TK, TPK, TCK, and TPCK level illustrates in Table 3.

Table 3 provides example responses to each of the open-ended items regarding TK, TPK, TCK, and TPCK. These are verbatim quotes selected from the responses of pre-service science teachers who completed the open-ended items at pre- and post the MLLS module. The naïve view respondent examples are taken from pre-tests and the more informed examples are taken from the post-tests. These views are presented along a continuum from naïve to more informed TK, TPK, TCK, and TPCK.
In summary, the results of this preliminary study provided evidences that pre-service science teachers’ TK, TPK, TCK, and TPACK has been fostered during their interacting with the MLLS module for pre-service science teachers. This finding is consistent with Jimoyiannis (2010), Jang and Chen (2010), Srisawasdi (2012), Srisawasdi (2014), and Srisawasdi and Panjaburee (2014) that implementation well-designed coursework could foster pre-service or in-service science teachers’ essential knowledge of TPACK.

6 Study limitations

Although the findings were framed in the literature on technology-integrated approaches in teacher education, this study was based on the implementation and evaluation of only one module of technology-integrated pedagogy in science of one science teacher education programme. Therefore, we should make it clear that our findings cannot be generalised to technology-integrated pedagogical approaches in different contexts. Another limitation of this study was the sample population utilised. The research study only recruited pre-service science teachers from a specific faculty of education at a small university that only offers one major of science education program, that is general science. Other majors of science teacher education programs should also be studied. In addition, the study was part of a research and development project which was specifically set up to try out and evaluate a technology-integrated pedagogical approach in science teacher education. Therefore, the conditions for the use of a technology-integrated pedagogy seemed to be optimal. It might be that in less optimal circumstances this pedagogy is evaluated less positively.

7 Contributions of the study

Despite this study’s limitations, the work provides three prominent contributions to the current literature base regarding integration of mobile technology in science teacher education program. This study provides teacher educators and scholars with empirical findings related to mobile technology integration strategies in science teacher education that promote the improvement of TK, TPK, TCK, and TPCK in context of mobile laboratory learning in science for pre-service teachers. Secondly, this study provides teacher educator researchers with an adapted alternative way to analyse and evaluate holistically teachers’ descriptive profile of TPACK into different level, i.e. Informed, Mixed, Naïve, and Unclear. Finally, this study offers an adapted TPACK framework for the innovative teaching strategy of inquiry-based science learning with the support of mobile MBL that can be utilised by researchers to investigate impact of the proposed strategy on pre-service science teachers’ TPACK.

8 Conclusion

This study reported an evaluation of a technology-integrated pedagogy module of mobile laboratory learning in science by inquiry on pre-service science teachers’ TPACK and the findings revealed the pre-service science teachers have been improved their TK, TPK, TCK, and TPCK after interacting with the module. Thus, this implies the possibility of
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promoting pre-service science teachers’ TPACK of mobile learning in science and it could be an effective way to develop their essential knowledge of mobile technology-enhanced learning in science to address the 21st century education requirement. However, more research needs to be conducted in order to maximise the improvement of pre-service science teachers’ TPACK by redesigning the module of mobile laboratory learning in science by inquiry. In addition, fully understand the transformation of knowledge related TPACK could be benefits to identify other pedagogical practices that may be useful as well. Yet, this study provides evidence of a positive starting point to design technology-integrated pedagogy module of mobile learning in teacher education program. However, teacher education programs need to provide enough technology-oriented understanding and skills for teaching and keep abreast of advancing mobile technologies in a dynamic field before the beginning of the early practice years.

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