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DEVELOPING TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE IN USING COMPUTERIZED SCIENCE LABORATORY ENVIRONMENT: AN ARRANGEMENT FOR SCIENCE TEACHER EDUCATION PROGRAM

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Over the last decade, traditional educational practices in teacher education have not provided prospective teachers with all the necessary skills for teaching students to acquire the skills to cope with the challenges of society in the 21st century. For this reason, there is a worldwide trend toward producing teachers with high teaching competency. To promote competency in using technologies to the teaching of specific content in the classroom context, the epistemology of Technological Pedagogical Content Knowledge (now known as TPCK or TPACK) is used as a basis for designing a particular arrangement of courses for science teacher education programs, thereby to help meet the needs of the 21st century teacher education development. In order to situate the transfer of how to cultivate TPACK in science teacher education program for others, this article demonstrates details of the alignment of courses for preservice science teacher preparation based on a proposed framework of a TPACK-based computerized laboratory environment for science teaching. Also, the implications of adaptation and the support of the transfer of the program would enable an effective transfer of design and practice in order to prepare preservice teachers in science teaching. The possibility of transferring such course arrangement to the other contexts of science teacher education programs could not be discounted.

Keywords: Curricular transfer; TPACK; microcomputer-based laboratory; computer simulation; inquiry learning.

1. Introduction

In the fast changing world of the early 21st century, technologies have become commonplace in improving and advancing the practice of science education because of their potential of bringing about change in ways of teaching and learning (Srisawasdi, 2012). For this reason, the effective use of technology in the classroom teaching process has become an important topic in research and development of the student learning process in science. Recently, the practice of science teacher education has been changing in this fast developing world of the early 21st century because of the potential of technology in changing ways of teaching and learning. As part of the changes, the state-of-art in teaching science is progressing through a wide range of the integration of pedagogical and technological activities that often benefit from the application of technology (Srisawasdi, Kerdcharoen, & Suits, 2008). To prepare and create a unique classroom environment for science teaching and learning, there is a requirement for comprehensive use of technology in order to develop students' proficiency in 21st century skills, support innovative teaching and learning, and create a robust educational support system for both students and educators (State Educational Directors Association et al., 2007). To better serve this aim, 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 technologies into their classroom teaching practice.

Over the last decade, in light of rapid technological advancement, traditional educational practices in teacher education no longer provide prospective teachers with all the necessary skills for teaching students to cope with society in the 21st century. As a part of the change, there is need for high quality teaching competency. To this end, there is a growing body of research to find ways to enhance preservice teachers' preparedness in integrating technological tools into their classroom teaching practices for specific subject domains. The challenge for teacher education this century is to discover effective ways to prepare literate preservice teachers and also to professionally develop in-service teachers. For science education, the current educational reforms encourage science teachers to integrate educational technology and inquiry-based teaching into their instruction for adding efficiency and value to both teaching and learning (Guzey & Roehrig, 2009, 2012). In the science education community of practice, there is a wide range of efficient technological environments and applications that can serve science teaching and learning (e.g. animations, simulations and modeling tools, microcomputer-based laboratories (MBL), intelligent tutoring systems, web resources and environments, spreadsheets, scientific databases, etc.) for both students and teachers. Many researchers have advocated the educational potential of ICT-based learning environments in science education, arguing that they provide opportunities for active learning, enable students to perform at higher cognitive levels, support constructivist learning, and promote scientific inquiry and conceptual change (Jimoyiannis, 2010). It is however, still not clear how best to prepare science teachers who are competent in using and managing educational technologies to support their teaching practice and enhance students' understanding of science concepts. The existing research reports suggest that experienced teachers seem reluctant to incorporate educational technology in schools, while preservice teachers and newly qualified teachers are more confident users of educational technology in classroom and are more willing to learn and adapt educational technology in their classroom practices (Madden, Ford, Miller, & Levy, 2005; Sime & Priestley, 2005; Anderson, 2006). In addition, a major obstacle of experienced teachers for using technology in the classroom is the lack of sufficient knowledge and skills of information and communication technology (ICT) (Efe, 2011). To overcome this obstacle, Smarkola (2008) has suggested training preservice teachers in educational technology during their initial teacher education. In addition, they can gain more confidence in using technology in their classroom teaching. To do so they will require a reasonable level of generic skills for integrating technology into classroom teaching in order to use computers as a part of the curriculum and a tool for authentic student engagement and learning (Sime & Pristley, 2005; Smarkola, 2008).

Based on the above rationale, the aim of this paper is threefold. The first is to illustrate a particular arrangement of courses for science teacher education program based on the TPACK framework. The second is to propose an integration of science teachers' professional knowledge about using MBL and computer simulations in inquiry-based science instruction. Finally, this paper aims to provide evidence of preservice science teachers' use of the TPACK framework resulting from the suggested teacher education program.

2. Essential Knowledge for the 21st Century Science Teacher

2.1. *Technological Pedagogical Content Knowledge (TPACK)*

Since the rapid growth of educational technology for several decades, the educational community has struggled to find its theoretical roots about technology in education and to develop fundamental frameworks with solid theoretical underpinnings (Roblyer, 2005; McDougall & Jones, 2006; Graham, 2011). In recognizing technology as an integral partner for education, a conceptual framework called Technological Pedagogical Content Knowledge (TPACK), which was built upon Shulman's (1986) Pedagogical Content Knowledge (PCK), was introduced to the educational research community. The 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 teachers could integrate technological tools into their teaching of specific content in their school practice (Jimoyiannis, 2010; Srisawasdi, 2012). The TPACK includes seven constructs that capture the different types of knowledge for effective integration of technology into teaching of content: (1) Content Knowledge (CK), which is the knowledge about the actual subject matter that is to be learned or taught; (2) Pedagogical Knowledge (PK), which is the knowledge about the processes and practices or methods of teaching and learning; (3) Technological Knowledge (TK), which is the knowledge about standard technologies and the skills required to operate particular technologies; (4) Pedagogical Content Knowledge (PCK), which is the knowledge about particular teaching practices that appropriately fit the nature of specific subject content; (5) Technological Content Knowledge (TCK), which is the knowledge in which actual subject matter could be manipulated into appropriate representations by the application of standard technologies; (6) Technological Pedagogical Knowledge (TPK), which is the knowledge about the existence, components, and capabilities of standard technologies that could be appropriately used to particularly support the processes of teaching and learning; and (7) Technological Pedagogical Content Knowledge (TPACK), which is the dynamic transactional relationship between knowledge about content, pedagogy, and technology in order to develop appropriate context-specific strategies and representations for better learning of content knowledge.

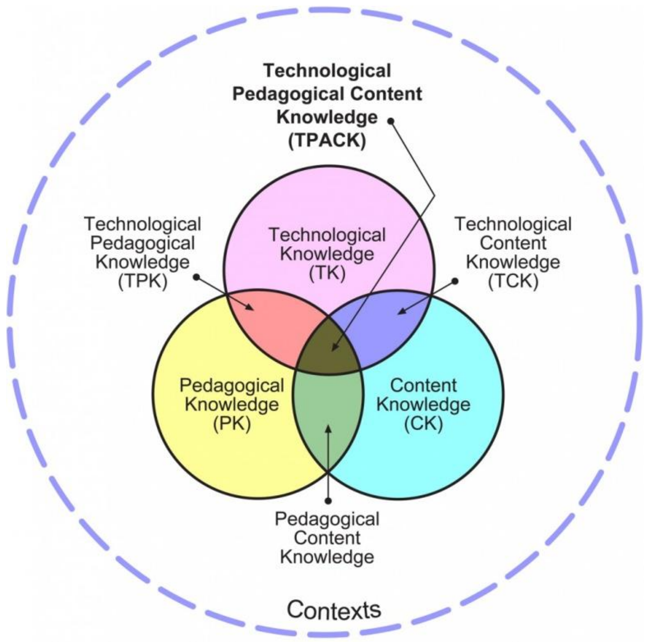


Figure 1. Technological Pedagogical Content Knowledge (TPACK) framework (http://tpack.org).

Figure 1 shows a Venn diagram with three overlapping circles of the three core categories of knowledge of the TPACK framework.

2.2. *TPACK and science teacher education*

Many educational researchers recognize the broad appeal and potential of the TPACK framework and it has been embraced as a theoretical basis for structuring information and communication technology (ICT) curriculum in teacher education programs (Chai, Koh, & Tsai, 2010; Jimoyiannis, 2010; Srisawasdi, 2012). For the science education community, the efforts of current science education reforms expect science teachers to integrate technology and inquiry-based teaching into their instruction (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996, 2000). To better prepare and promote the competency of 21st century science teachers, the epistemology of technological pedagogical content knowledge (TPACK) is currently considered as the essential knowledge for highly qualified science teachers. In this light, researchers have extensively introduced the TPACK framework to preservice (Jang & Chen, 2010; Alayyar, Fisser, & Voogt, 2012), and in-service science teachers (Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Jimoyiannis, 2010; Guzey

Table 1. A summary of TPACK-based science teacher education development program.

Authors	Target group	Strategy	Technology used
Niess (2005)	Preservice science teachers	1-year coursework	Calculator-based ranger (CBR) or calculator/computer-based laboratory (CBL) probes
Hennessy et al. (2007)	In-service science teachers	3-year training program	Computer simulation, data logging, Interactive white board
Guzey & Roehrig (2009)	In-service science teachers	Training program	Various ICT tools (probeware, mind-mapping tools, computer simulations, digital images, and movies)
Jimoyiannis (2010)	In-service science teachers	Coursework	Various ICT tools (computer simulations, modeling, spreadsheets, presentation software, conceptual mapping, MBL, Web Quests)
Jang & Chen (2010)	Pre-service science teachers	1-semester coursework	Various ICT tools (multimedia authoring tools, presentation tools, communication/social tools, collaboration tools, organization/mapping tools, metacognition/planning tools)
Alayyar, Fisser, & Voogt (2012)	Pre-service science teachers	Online training program	ICT
Annetta et al. (2013)	In-service science teachers	Workshop	Video game

& Roehrig, 2012; Annetta et al., 2013). According to the utilization, Table 1 shows a summary of applying TPACK in science teacher education and development.

However, there has been limited research on the development and implementation of the TPACK framework in science teacher education programs. In particular the research literature exploring the development of TPACK among preservice science teachers is limited. Moreover, there has been no consensus on the nature and development of TPACK among science teacher educators and researchers in order to meet the challenges of science teacher education for the 21st century.

2.3. *Computerized laboratory environment for science instruction*

For several decades, computer technology has significantly dominated research in the natural sciences, for example, by making visible the things that are too small, too big, too fast, too slow or too complex for the human perception, and modeling data based on measurements of digital surveying instruments to enable making more precise predictions than ever before. Therefore, computer technology is also expected to have a similar impact on science instruction. Computer technologies are receiving increased attention from the science education community because of their potential to support new forms of science instruction and overcome difficulties normally associated with constructivist, inquiry-based learning and teaching (Srisawasdi et al., 2008). In addition, they can help transform the science classroom into a learning environment where students are engaged in actively constructing deep understanding of science concepts and process through inquiry (Linn, Layman, & Nachmis, 1987; Tinker & Papert, 1989; Novak & Krajick, 2006). Finally, the use of computer technology has become a core approach to developing scientifically and technologically literate citizens.

Computer technology has been widely used in teaching and learning science to (1) model proposed knowledge structures or learning patterns, (2) develop more in-depth and integrated understanding of concepts and process, (3) enhance the development of scientific skills, (4) visualize complex and dynamic scientific phenomena, (5) promote collaborative network in the community of learning for the construction of knowledge and sharing of data, (6) support access to a variety of information, (7) support collecting various types of scientific data, (8) test underlying theories through diagnostic or tutorial strategies, and (9) enhance characteristics of inquiry as the way scientists work. With reviewing of empirical evidence it is clear that computer technology can improve learning in science. In this paper, I discuss two uses of computers in science laboratory environments that can be particularly advantageous, namely microcomputer-based laboratory (MBL) and computer simulations. Figure 2 displays the computerized learning environments of microcomputer-based laboratory and computer simulation used in science education.

Figure 2. An example of microcomputer-based laboratory (left) and computer simulation (right) for science teaching and learning.

3. An Adaptation of TPACK in the Science Teacher Education Program at Khon Kaen University, Thailand

3.1. *A conceptual framework based on TPACK*

Recent research indicates that educational technologies, including digital media, probeware, modeling tools, computer simulations, and virtual collaborative environments can effectively support teachers' teaching practices in integrating inquiry-based instruction in their science classrooms. To be most effective, educational technologies should be situated in a flexible framework of knowledge of content, pedagogy, and technology (Maeng, Mulvey, Smetana, & Bell, 2013). Due to the demanding use of educational technologies to support inquiry teaching and learning, teachers' knowledge of content, pedagogy, and technology and their interaction is necessary for successful integration of educational technologies into the science classroom. This paper proposes an integrative framework of essential knowledge for using MBL and computer simulations in inquiry-based physics learning as presented in Figure 3.

3.2. *Participants and context*

A coursework was designed for preservice science teacher in physics teaching major in the Science Education Program at Faculty of Education, Khon Kaen University, Thailand. The program is a 5-year science teacher education initiative. Science teachers have to enroll in all compulsory coursework for four years and then complete one year of school internship. They take major physics courses at the Faculty of Science and method courses at the Faculty of Education. The series of coursework was first implemented during the school years 2009-2011 and the author was the course coordinator.

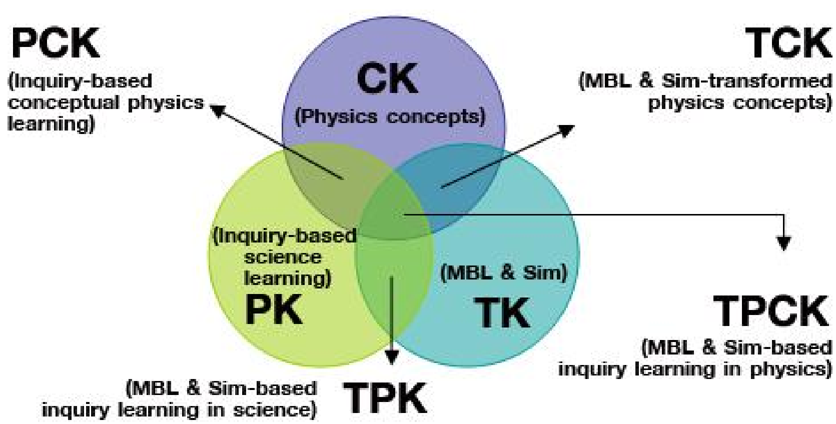


Figure 3. An integration of science teacher's professional knowledge for using MBL and computer simulation in inquiry-based physics instruction (Adapted from Mishra & Koehler, 2006).

3.3. *Details of the courses*

In order to prepare a comprehensive TPACK program that integrated educational technologies for preservice science teachers, a series of coursework in a science teacher education program is presented in this paper. At the faculty of Education, Khon Kaen University, preservice science teachers in physics teaching major completed a sequence of three methods courses across multiple semesters. These courses included a course in computerized laboratory practices in science teaching for all majors (physics, chemistry, biology, and general science), a teaching of physics concepts in school science methods course, and a research in science teaching and learning course for all majors. Figure 4 illustrates examples of preservice science teachers' work in a computerized laboratory environment including MBL and computer simulations using open-inquiry science activities.

After the course in computerized laboratory practices in science teaching, the preservice teachers learned how to teach physics concepts in a school science course with the use of MBL and computer simulations through micro-teaching and peer learning processes. Figure 5 illustrates an example of a micro-teaching activity for preservice science teachers.

Finally, the preservice science teachers designed their own teaching program to be implemented in the science classroom. They were engaged in conducting a Science Lesson Study using MBL and computer simulations for enhancing inquiry learning among secondary school students. Figure 6 displays the classroom teaching process of Lesson Study for the development of science teaching and learning.

To describe the features of the learning environment in the course arrangement and show how it works in science teacher professional development, Table 2 presents an overview of the methods courses in relation to the TPACK framework and strategies for preservice science teacher learning.

Figure 4. Examples of computerized open-inquiry science activity for preservice science teachers in a course of Computerized Laboratory Practice in Science Teaching (1st course).

Figure 5. Micro-teaching activity by the use of MBL and computer simulation for preservice science teacher in a course of Physics Concepts in School Science (2nd course).

3.4. *Evidence of preservice science teachers' TPACK*

During four weeks of open-forum discussions in an ICT case-based module for physics teaching and learning, the qualitative method of participant observation was used to document preservice science teachers' conversations of the discussion. Students shared what they learned in the ICT case-based module and the instructor observed the content of the conversation. The observation method is useful to researchers because it gives the researcher better understanding of the context and phenomenon under study as objectively and accurately as possible given the limitations of the method (Dewalt & Dewalt, 1998; Kawulich, 2005). In the open-forum discussions, the instructor collected data from the preservice science teachers' points of view. After completing a case presentation, the students were encouraged in critical open discussion to consider the potential impact of the case on students' learning and the TPACK framework. The case discussion was aligned to the main points as displayed in Table 3. After transcription of their conversations, qualitative content analysis was conducted to examine aspects of their communication, in order to interpret and to summarize the preservice science

Figure 6. An example of preservice science teacher's teaching in class by the use of MBL and computer simulation in a course of Research and Development in Science Teaching and Learning Process (3rd course).

teachers' TPACK. Qualitative content analysis is a method that is used to analyze text data that focuses on the characteristics of language as communication with attention to the content or contextual meaning of the text (McTavish & Pirro, 1990; Tesch, 1990). Table 3 also shows evidence of the preservice science teachers' TPACK obtained from the open-forum discussion.

Table 2. Details of the alignment courses for preservice science teacher preparation based on TPACK.

Course	Student	Week	Domain	Learning strategy	Knowledge object
Computerized Laboratory Practice in Science Teaching (1st course)	Year 2	1-2	Introduction to computerized laboratory practice in science teaching	Interactive lecture	PCK
		3-7	Laboratory practice with microcomputer-based laboratory (MBL) and computer simulation	Hands-on practice	CK, PK, TK, TCK, TPK
		8-9	Introduction to inquiry-based science teaching and learning	Interactive lecture	PK
		10-15	Research and development of inquiry-based science learning with technology (Phase 1)	Hands-on practice	PCK, TCK, TPK, TPCK
Physics Concepts in School Science (2nd course)	Year 3	1-2	Introduction to learning factors related understanding in physics concept	Interactive lecture	PCK
		3-8	Analysis of physics concepts, teaching strategies, and technological tools	Hands-on practice	CK, PK, PCK, TPCK
		9-15	Research and development of inquiry-based science learning with technology (Phase 2)	Hands-on practice, micro-teaching	PCK, TCK, TPK, TPCK
Research and Development in Science Teaching and Learning Process (3rd course)	Year 4	1-2	Introduction to lesson study method for professional teacher	Interactive lecture	PCK
		3-4	Introduction to technological pedagogical and content knowledge for professional teacher	Interactive lecture	-
		5-8	ICT case-based module for physics teaching and learning	Interactive lecture	CK, PK, TK, PCK, TCK, TPK, TPCK
		9-15	Research and development in physics teaching by lesson study method	Hands-on practice, classroom teaching in school science	TPCK

Table 3. Preservice science teacher's TPACK obtained from the open-forum discussion.

Knowledge object	Point of open-forum discussion	Example of student response during open-forum discussion
CK	Identification of content taught and its relationships to topic	Example A: "Sound wave is a longitudinal wave which shows property of wave as same as light wave" Example B: "For topic of electrical circuit, there are three ways of connected circuit: series, parallel, and mix circuit"
PK	Identification of teaching strategy used and its pedagogies (its strategic features)	Example A: "This case used open-ended activity of scientific inquiry because student have to design their own experiment addressed provided inquiry question about sound wave propagation" Example B: "In the learning with electrical circuit simulation, student conducted the experiment through open-inquiry science learning process by design, collect, analyze, and conclude their own experiment with friends"
TK	Identification of technological tool utilized and its features	Example A: "MBL was used to collect and graph experimental data and computer simulation was used to visualize the phenomena of sound wave at unobservable level" Example B: "The simulation provide opportunity for student to manipulate resistance, light bulb, battery, and so on, in order to investigate electrical experiment"
PCK	Identification of content difficulty to be taught by traditional means; evaluation of the strategy used	Example A: "The property of sound wave cannot observe directly by eyes. There need a particular experimental equipment to help detect the wave of sound. So, student were challenged to investigate the sound wave phenomena by using MBL probeware and simulation in the way of their own thinking" Example B: "In order to test their own understanding about electrical circuit, for example, the difference between series and parallel circuit, student were challenged to independently manipulate virtual electrical device in order to explore the results and test what they think about the topic"
TCK	Identification of representation barrier to be represented by traditional means; evaluation of the tool used	Example A: "For MBL tool, it is better than the conventional classroom that its software is able to represent immediately both graphical and numeric data, not only textual data like in textbook" Example B: "Conventionally, student did this experiment with real electrical devices that they cannot observe the way of electron flow within any circuit. For the use of simulation, they can select to see the electron flow and switch to see particular symbolic for each electrical device in circuit"
TPK	Identification of practical difficulty to be implemented by traditional means; evaluation of the tool used	Example A: "For this topic, MBL tool can serve to investigate property of sound wave in different conditions depended on design of experiment. Therefore, it could be used appropriately to facilitate the open-inquiry science activity" Example B: "Conventionally, student did this experiment with real electrical devices based on teacher direction. For the use of simulation, they can select independently virtual electrical devices and perform the experiment as much as they want based on their own ways of investigation"
TPCK	Identification of strategic harmonization among content, strategy, and tool, and its impact on student learning; proposing features to be added or deleted by the harmonization	Example A: "The MBL is an effective support tool for conducting open-inquiry science activity because of its function of rapid detection, immediately graphical display, and … Thus, they could investigate the study phenomena as long as their own design of experiment and the obtain data provide them an easier to making data meaning and understanding" Example B: "Because of simulation is computer-simulated experiment, student can do experiment with the simulation as much as they want to know, especially following their own design of experiment Moreover, it provides unobservable visualization of the study phenomena to student when they interact with"

4. Implications of Adaptations for Development of Preservice Teachers' TPACK

In light of my experience, I suggest a particular arrangement of coursework in order to prepare preservice teachers by following a developmental progression in TPACK. The developmental progression model was grounded from Everett Rogers' (2003) idea of the innovation-decision process. Table 4 displays the alignment courses for preservice science teacher preparation based on a developmental progression in TPACK.

In order to develop preservice teachers' TPACK, the preservice teacher should progress through the following five-stage developmental process when learning to integrate a particular technology in teaching and learning of any subject content (Niess, 2011).

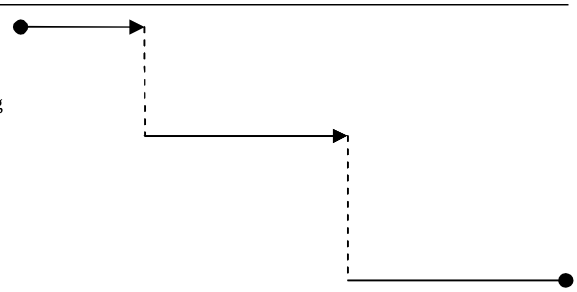
(1) Recognizing (knowledge) – where teachers are able to use the technology and recognize the alignment of the technology with subject matter content, yet do not integrate the technology in teaching and learning of the content.

(2) Accepting (persuasion) – where teachers form a favorable or unfavorable attitude toward teaching and learning specific content topics with an appropriate technology.

(3) Adapting (decision) – where teachers engage in activities that lead to a choice to adopt or reject teaching and learning specific content topics with an appropriate

Table 4. An illustration of a developmental progression in TPACK for development of science teacher's professional knowledge in using MBL and computer simulation into inquiry-based science instruction.

Course	The developmental progression in TPACK based on model of the innovation-decision process				
	Recognizing	Accepting	Adapting	Exploring	Advancing
1. Computerized Laboratory Practice in Science Teaching (1st course)					
2. Physics Concepts in School Science (2nd course)					
3. Research and Development in Science Teaching and Learning Process (3rd course)					



technology.

(4) Exploring (implementation) – where teachers actively integrate teaching and learning of specific content topics with an appropriate technology.

(5) Advancing (confirmation) – where teachers redesign the curricula and evaluate the results of the decision to integrate teaching and learning specific content topics with an appropriate technology.

Based on my experience of preparing preservice science teachers' TPACK by designing a particular arrangement of coursework in a science teacher education program, the following are general considerations:

- *Preservice teachers need to possess digital literacy before development of TPACK.*

In light of my experience, teachers' digital literacy plays a pivotal role in the implementation of TPACK in the classroom. The teachers should be able to create and communicate digital compositions. Being able to search for meaningful information and evaluating its accuracy and relevancy for domain content is a necessary skill for locating and using digital content (Leu et al., 2008). The implementation of digital content in the classroom is an important and effective method of facilitating, enhancing and encouraging personalized students' learning (Bakkenes, Vermunt, & Wubbles, 2010). As a result, the teacher has to create digital content from a variety of digital resources to meet the needs of every student. At the same time, the created digital content must be communicated effectively using web-based tools in order to be a useful educational medium (Merchant, 2003). Similar findings have been documented in the research literature that suggest that digital literacy is necessary for teachers to be able to use TPACK in teaching (Jones, Harlow & Cowie, 2004; Finger & Houguet, 2009).

- *Preservice teachers' perceptions and attitudes toward technology is a major predictor of future technology use in classroom teaching.*

How teachers teach, think, and learn influence teachers' perceptions, attitudes and beliefs (Richardson, 1996). When teachers use a technology as a tool in a teaching and learning environment, they must be willing to change their role in the classroom as a facilitator to facilitate students' active learning. This leads to teachers' perceptions, attitudes and beliefs toward technology adoption is one of the factors that affects the success or the failure of TPACK implementation (Sugar, Crawley, & Fine, 2004). Regarding teachers' perceptions, attitudes and beliefs toward the effect of technology on TPACK implementation, past experience has shown that teachers with knowledge, understanding, and experience on computers and technologies have more positive attitudes toward the potential of technology in education. To gain knowledge, understanding, and experience about computers and technologies, teachers should know how computers and technologies work and operate. It means that the more knowledge, understanding, and expertise teachers possess, the more knowledge and confidence they can gain, resulting in more positive perceptions, attitudes and beliefs and potentially improving their views regarding technology integration in teaching and learning. Several researchers agree that teacher knowledge, understanding, and expertise about computers and technologies are major factors in the adoption and successful use of technologies (Violato, Marini, & Hunter, 1989; Francis & Evans, 1995). From this point of view, it is clearly recommended that teacher education programs need to include introductory computer and technology courses. After experiencing these courses, the teachers could reduce computer anxiety and gain competency in skills and confidence in using technology in TPACK (Anderson & Maninger, 2007; Abbitt, 2011).

5. A Support for the Transfer to Other Contexts

Research has shown that success in the use of technology in education depends largely on teachers' level of skill in integrating technology into the teaching process and in utilizing technology to provide learner-centered education. Unfortunately, research has also reported that most teacher education programs in both developed and developing countries are mainly focused on the development of computer skills for developing teachers' teaching ability in using technology. Limited attention has been given to developing a pedagogy in the use of technology in order to raise the capacity of teachers to utilize technological tools effectively in their teaching or to improve teacher education.

As is the case of developing TPACK for preservice science teachers described above, this section describes a unique program to support the development of TPACK in a course in Computerized Laboratory Practice in Science Teaching. The program enables the development of computerized laboratory skills and pedagogical practice of teaching science in a computerized laboratory environment. This study may situate the transfer in design of course materials and the development of adaptable curricular for other contexts. Details of a Computerized Laboratory Practice in Science Teaching course are as follows:

- ❑ To support the construction of comprehensive understanding of scientific conceptual knowledge for preservice science teachers, the attributes and connections of the scientific conceptual knowledge in the school science curriculum have to be clearly verified, supported by the following instructional tools.

Table for Analyzing Attributes of Science Concept

(**Step 1:** Discovering targeted science concept's attributions)

Strand	Level	Learning Standard	Indicator	Learning Area (Targeted Science Concept)	Attributes of the Targeted Science Concept		
					Concepts which need to know before	Concepts which relate to the targeted concept	Concepts which have to know for next

Figure 7. An example of table for analyzing attributes of science concept.

- A table of analysis of science concepts in the school science curriculum detailing required components for analyzing the essential concept and the situated concept (see Figure 7).
- Construction of concept map using a computer application (e.g. Free Mind software) to simplify essential and needed concepts and its connections for student learning (see Figure 8).
- A table of analysis of hierarchical and situational scientific concepts detailing its conceptual explanation (see Figure 9).

❑ To experience the computer-based technological use in classroom laboratory teaching (both actual and virtual lab) preservice science teachers needed to: (a) learn the relevant technical knowledge and be trained to use the technologies (including hands-on microcomputer-based laboratory obtained from Vernier Software & Technology, LLC., and interactive computer simulations obtained from the Physics Education Technology (PhET) Project at University of Colorado, Boulder, both hardware and software application), and (b) practice investigating physical phenomena by conducting the

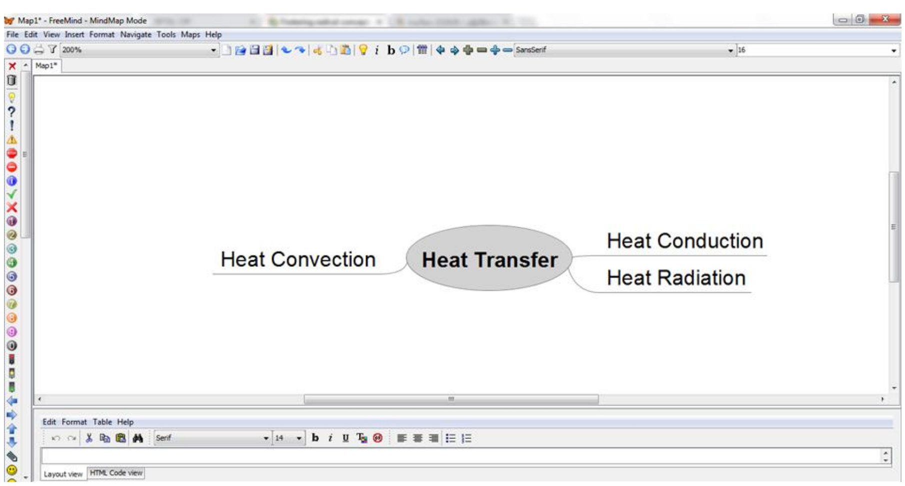


Figure 8. An example of a physics concept map using Free Mind software.

Table for Analyzing Hierarchical & Situational Science Concepts
(Step 1: Discovering targeted science concept's attributions)

Scientific Situation	Major Science Concept	Minor Science Concept (1st Order)	Minor Science Concept (2nd Order)
Situation 1:	Major 1:	Minor 1:	Minor 1-1:
			Minor 1-2:
		Minor 2:	Minor 2-1:

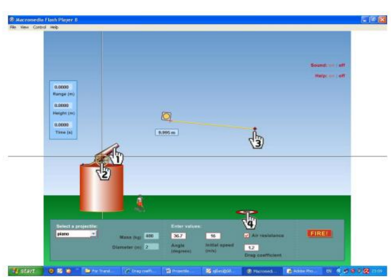
Figure 9. An example of table for analyzing hierarchical and situational science concepts.

processes of inquiry-based science laboratory. Instructional tools that provide support include:

- Laboratory manual for practicing computer-based laboratory and simulations detailing lab objectives, lab materials, lab procedures, and lab data analysis (see Figure 10).
- A series of laboratory worksheets for conducting computer-based laboratory and simulations for designing experiment and for writing lab report (see Figure 11).

❑ To enhance preservice science teachers pedagogic use of instructional technologies to teach scientific conceptual knowledge, they were required to perform fundamental processes for developing science teaching practices step-by-step facilitated by instructors, and were required to collect authentic data from science classrooms in school science. Instructional tools of support include:

- A series of activities, based on the Dual-situated Learning Model (DSLM) (She, 2004) on selected science concepts detailing developing sequences of science teaching practice consisting of discovering the concept's attributes probing students' existing conceptions, analyzing students' alternative conceptions, designing mental set of situations for students learning, and planning a particular science lesson for classroom teaching.



○ ค่าแสดงผลต่างๆ ในการเคลื่อนที่ของวัตถุแต่ละวัตถุจะถูกนำเสนอในปริมาณทางวิทยาศาสตร์ของ ***ระยะทางการเคลื่อนที่ได้ในแต่ละระยะของวัตถุ "Range (m)", ระดับความสูงในการเคลื่อนที่แต่ละระยะของวัตถุ "Height (m)", ระยะเวลาที่ใช้ในการเคลื่อนที่แต่ละระยะของวัตถุ "Time (s)"*** โดยที่สามารถที่จะใช้เม้าส์ไปวางไว้ในจุดต่างๆ ที่แสดงบนเส้นวิถีการเคลื่อนที่ของวัตถุเพื่อจะดูข้อมูลในส่วนดังกล่าวได้ ดังแสดงในภาพด้านล่าง

Figure 10. An example of lab manual for practicing computer-based laboratory and simulation.

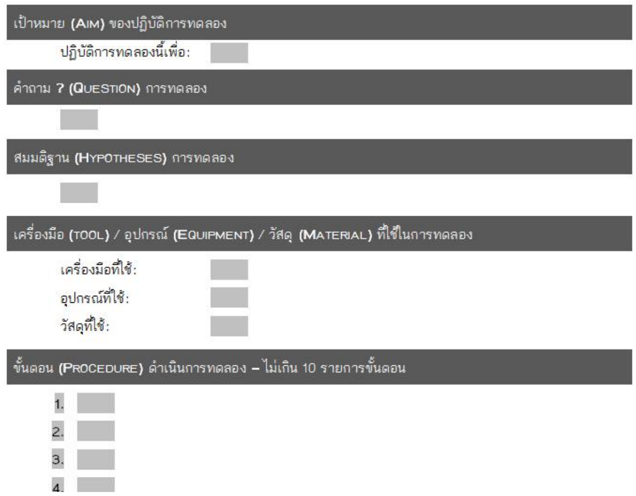


Figure 11. An example of lab report worksheet after conducting computer-based laboratory and simulation.

6. A Closing Thought

As the TPACK is currently considered as possessing the essential qualities of knowledge for highly qualified teachers in the 21st century, it has been suggested by researches to be helpful in preparing literate preservice teachers and also to develop in-service teachers professionally in the use of technology in their classroom teaching practices of specific subject contents. This paper proposed an adapted conceptual framework of TPACK for the particular use of microcomputer-based laboratory and computer simulations in inquiry-based science learning. The paper also illustrates the pedagogical arrangement of coursework into the TPACK framework. Moreover, implications for developing preservice teachers' comprehensive TPACK and support of the transfer to other contexts were clarified. The preliminary success of the coursework arrangement could be described in examples of student responses. The course arrangement of the science teacher education program has potential to be viable and in helping the development of preservice science students' TPACK. However, the improved TPACK at the end of the course arrangement has not been investigated as yet.

This study illustrates a successful and promising practice for preparing secondary science teachers in Thailand. For Thailand and other emerging economies, policy makers can use this information as a guideline for pre-qualifying preservice teachers who are going to be science teachers of the future. Moreover, they may position TPACK as a central tenet of teacher professional development and to aid in the introduction of cutting-edge instructional technologies into school practices. For teacher educators, they have an additional research area of educating preservice science teachers to becoming skillful teachers, and for enabling in-service science teachers to become experienced professional teachers by using applicable technologies in the 21st century. In particular, the possibility of transferring such course arrangement to other contexts of science teacher education programs could be developed. The TPACK framework could be a medium for developing preservice science teachers essential knowledge and competency in using technology pedagogically in the science classroom.

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