Fostering Pre-service STEM Teachers' Technological Pedagogical Content Knowledge: A Lesson Learned from Case-based Learning Approach

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Abstract: As the recent demand for human resources in science, technology, engineering, and mathematics (STEM), the development of professional STEM teacher is called worldwide. It is becoming a critical need in teacher education in order to educate student teachers, and prepare pre-service and beginning teachers for high quality of teaching competency. To promote the competency for 21st century STEM teachers, the epistemology of technological pedagogical content knowledge (TPACK) is currently considered as the essential qualities of knowledge for highly qualified teachers.

The aim of this study is explore the effect of case-based learning approach on TPACK competency of pre-service STEM teachers. In order to develop the pre-service teachers' competency regarding effective integration of technologies into teaching specific content areas, a series of innovative case study teaching in science and mathematics was presented to 43 participants of pre-service physics, chemistry, biology, mathematics, and computer teachers during a course of information and communication technology (ICT) in Education at Khon Kaen University, Thailand. After finishing a case presentation, the pre-service teachers were encouraged into a forum of critical open discussion by considering the potential impact of the case and the TPACK framework. They were investigated instructional design competency of using ICT tools into student learning process and their personal beliefs about ICT in educational process both before and after. The participant's reactions and learning was evaluated by using a self-reported questionnaire and an implementation log of content-specific learning process design, respectively. Results showed a change of their beliefs and the transformation of their TPACK competency in STEM teaching.

In an effort to better serve the needs of high quality STEM teachers, the results of this study illustrated that the competency of TPACK could be particularly considered as a core attributes for future STEM teachers. By the way, case-based learning approach can play an effective part in preparing and professing the TPACK competency for STEM teachers.

Keywords: TPACK, ICT, Case-based approach, Pre-service Teacher, STEM

1. Introduction

In an alarming trend that can have severe profound and accelerating changes in the 21st century society, educational leaders and policy makers have underscored the importance of STEM—the catchy shorthand for "science, technology, engineering and mathematics"— education areas in preparing literate students for more than a decade. Not only all students need a more robust STEM education, but STEM teacher also are need to

educate and prepare for gaining high quality of teaching competency. To prepare and create a unique classroom environment for STEM teaching and learning, there is a requirement for comprehensively use of technology in order to develop proficiency in 21st century skills for student, support innovative teaching and learning, and create robust education support system for both students and educators (State Educational Directors Association et al., 2007). Technologies has profound and lasting impacts in school classroom as being a powerful cognitive tool that can transform the way core subject is taught by facilitating both teachers' instructional practices and students' learning processes (Edelson, 2001). Thus, to promote the competency for 21st century STEM teachers, the epistemology of technological pedagogical content knowledge (TPACK) is currently considered as the essential qualities of knowledge for highly qualified teachers. Furthermore, viewing of teachers' knowledge as including rich relationships between content, pedagogy, and technology also has significant implications for teacher education and teachers' professional development (Kohler, Mishra, & Yahya, 2007). The goal of this study was to explore the case-based approach in the context of pre-service STEM teachers' preparation and development. The study focused on investigation of the transformation of TPACK competency in the pre-service STEM teachers and their change of personal belief toward benefits of ICT in education

2. Literature Review

2.1 Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework was built upon Shulman's (1986) pedagogical content knowledge (PCK) work, idea of knowledge of pedagogy that is applicable to the teaching of specific content, and it has been embraced as a theoretical basis for structuring ICT curriculum in teacher education programs (Angeli & Valanides, 2009; Chai et al., 2011; Jimoyiannis, 2010). The TPACK was firstly proposed by Mishra and Koehler (2006) to describe an integrated connection among content knowledge, pedagogical knowledge, and technological knowledge in order to aid the potential integration of ICT tools in classroom setting and school practices. Mishra and Koehler (2006) postulate seven constructs that capture the different types of teachers' professional expertise needed for effective technology integration including: (1) content knowledge; (2) pedagogical knowledge; (3) technological knowledge; (4) pedagogical content knowledge; (5) technological content knowledge; (6) technological pedagogical knowledge; and (7) technological pedagogical content knowledge. TPACK may provide new directions for teacher educators in solving the problems associated with infusing ICT into classroom teaching practice and learning process (Chai et al., 2011). Researches on teacher education reported that the TPACK model can be used as a potentially fruitful framework to prepare and develop teacher competencies in school teaching (Doering et al., 2009; Lee & Tsai, 2009; Voogt et al., 2009).

2.2 Case-based Approach

The case study method was originated from medical and business schools and it was used as active learning pedagogy for exploring particular principles and solving problems (Cranston-Gingrass et al., 1996; Sykes & Bird, 1992). Case-based approach was determined as a tool for teacher professional preparation and development and it becomes a means for effective method in order to facilitate critical thinking and exploring dilemmas in classroom-based teaching (Dori & Hercovitz, 2005). This approach has been supported within a constructivist learning paradigm in which pre-service teachers were provided

opportunities to explore various issues within real-life scenarios of student-centered classroom, moving knowledge from theory into practice to become thoughtful practitioner (Lee, Summers & Garza, 2009).

3. Method

3.1 Study participants

The participants for this study included 43 pre-service STEM teachers in Graduate Diploma Program in Teaching Profession at Faculty of Education, Khon Kaen University, and they were five physics major, 11 chemistry major, eight biology major, nine mathematics major and 10 computer science major. They were attending a course of information communication technology (ICT) in Education during the 2nd semester of academic year 2010 and they were invited to participate in this research. The participants were aged 21 to 24 years, and about 63% (27 of 43) were women. All of them did have satisfactory basic ICT skills but they had not any experience with using ICT for teaching before.

3.2 The Case-based ICT module

The case-based ICT module consisted of 6 three-hour weekly lecture and the module included six case studies on integrating ICT for STEM education. Table 1 presents the cases and its details of technology, pedagogy, and content used, which used in this study.

Table 1 Details of the case-based ICT module

Case	Lesson name	Technology used	Pedagogy used	Content used
1	computer-based laboratory environment for authentic-inquiry science	Computer-based laboratory	Inquiry-based learning	Nanoscience and technology of smell (Nanoscience)
2	Virtual computer-based laboratory environment for chemistry learning	Computer simulation	Inquiry-based learning	Water contact angle (Chemistry)
3	Symbolic tool set for integral problem solving in mathematics learning	Maple software	Problem-based learning	Calculus (Mathematics)
4	Constructivist web-based learning environment for physics learning	Web-based learning environment	Constructivist learning	Force and laws of motion (Physics)
5	Testing and diagnostic learning problem – an educational application from computer science	Web-based Artificial intelligence	Web-based learning	System of linear equation (Mathematics)
6	Geographic information system tool for teaching biology	Geographic information system (GIS)	Inquiry-based learning	Mollusk diversity and distribution (Biology)

After finishing a case presentation, the participants were encouraged into a forum of critical open discussion by considering the potential impact of the case on students' learning and the TPACK framework. The case discussion is aligned to the criteria for ICT-TPACK (Angeli & Valanides, 2009) comprising: (a) identification of suitable topic to be taught with technology; (b) identification of appropriate representations to transform content; (c) identification of teaching strategies difficult to be implemented by traditional

mean; (d) selection of appropriate tools and appropriate pedagogical uses of their affordances; and (e) identification of appropriate integration strategies.

3.3 Data collection

For investigating the TPACK transformation of the participants in this study, the two design tasks of using ICT tools into their teaching practice and student learning process constituted the unit of analysis. The first design task was assigned to the participants in the first week of the case-based ICT module, before the presentation of the first case study. At the end of the module, the participants were assigned to complete the second design task of using ICT into their teaching. Also, all the participants were asked to respond to a 17-item survey instrument, which obtained from Jimoyiannis & Komis (2007), for exploring their belief about ICT in education both before and after attending the case-based ICT module. The instrument was a Likert-type scale containing items that present statement of belief about ICT as a teaching and learning tools (6 items), belief about ICT integration in education (6 items), and belief about ICT in the educational process (5 items). Each item rated the participants' belief using a five-point-scale ranging from "strongly disagree" (1 point) to "strongly agree" (5 points).

3.4 Data analysis

For the analysis of the transformation of TPACK competency for the participants, the content analysis was primarily used for the analysis of their design tasks. A coding system of protocols consistent with the TPACK framework was developed and then the design tasks were coded based on the seven categories defined by the TPACK framework, including Content knowledge (C), Pedagogical knowledge (P), Technological knowledge (T), Pedagogical content knowledge (PC), Technological content knowledge (TC), Technological pedagogical knowledge (TP), and Technological pedagogical content knowledge (TPC). To analyze the pre-service STEM belief about ICT in education, descriptive statistics was used to process the students' responses from the questionnaire.

4. Results and Discussion

4.1 Results for teachers' TPACK competency

In Table 2 that follows, it presents the percentage of coded segments over the first and second design tasks for each of seven categories, as abovementioned. The statistical analyses of the data suggest that there are some differences between the first and the second design tasks that the percentage of C, T, PC, TC, TP, and TPC for the first design task is greater than the second design task, except for the percentage of P.

Table 2 Percentage of each coding category for both design tasks

Design task	Category of TPACK framework						
	C	P	T	PC	TC	TP	TPC
First (N=43)	30.23	100.00	97.67	16.27	27.90	90.67	13.95
Second (N=40)	70.00	100.00	100.00	70.00	67.50	97.50	65.00

A graphical representation of the Table 2 is provided in Fig. 1, which allows us to see some interesting transformation of TPACK competency for the pre-service STEM teachers.

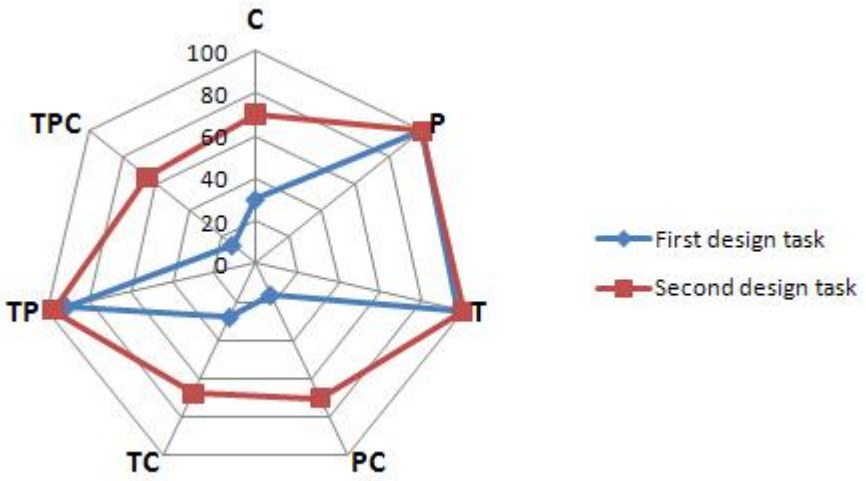

Figure 1 Knowledge transformation of pre-service STEM teachers' TPACK competency

In summary, the results provided evidence that the pre-service STEM teachers' TPACK competency has been transformed through the case-based ICT module. The results also reflect that the pre-service STEM teacher can present their knowledge of content (C), pedagogical content (PC), technological content (TC), and technological pedagogical content (TPC) more fully after attending the module. The result is consistent with research findings that case-based teaching for teacher professional development induced a significant change in their abilities high-quality learning activities (Dori & Hercovitz, 2005). Moreover, Chai et al. (2011) reported the use of the core ICT module to model pre-service teachers' TPACK that the pre-service teachers' perceived relations between content knowledge and TPACK changes form insignificant to significant.

4.2 Results for teachers' belief about ICT in education

Table 3 shows the mean and standard deviation of pre-test and post-test on the belief about ICT as a teaching and learning tool (ICT-Tool), belief about ICT integration in education (ICT-Integration), and belief about ICT in the educational process (ICT-Process) for pre-test and post-test. The statistical analyses of the data suggest that there are some differences between the pre-test and post-test scores for teachers' belief about ICT in education that the mean of ICT-Tool and ICT-Process for the post-test is greater than the pre-test, except for the mean of ICT-Integration.

Table 3 Mean and standard deviation of each dimension for teachers' belief about ICT in education

Testing	Dimension of belief about ICT in education		
	ICT-Tool	ICT-Integration	ICT-Process
Pre-test (N=41)	3.78 (0.86)	3.76 (0.68)	3.36 (0.47)
Post-test (N=34)	3.88 (0.72)	3.75 (0.87)	3.50 (0.43)

A graphical representation of the Table 3 is provided in Fig. 2, which allows us to see some belief change of the pre-service STEM teachers.

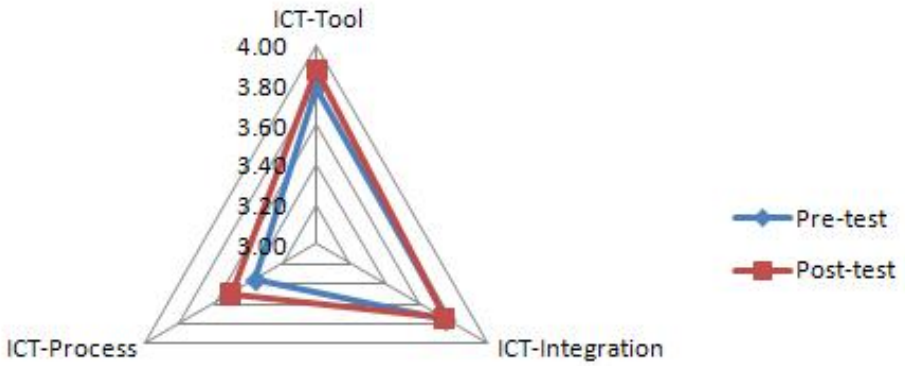

Figure 2 Pre-service STEM teachers' belief change about ICT in education

In summary, the results provided evidence that the pre-service STEM teachers' belief about ICT in education has been changed by the case-based ICT module. The results also reflect that the pre-service STEM teachers' belief change was occurred at the belief about ICT as a teaching and learning tool (ICT-Tool) and the belief about ICT in the educational process (ICT-Process) after attending the module, except for the belief about ICT integration in education (ICT-Integration). Support for the results was reported by Jimoyiannis & Komis (2007) that teachers exhibited increased motivational and willingness to adopt ICT in education after they were exposed to ICT and case-based instruction effect change in pre-service teachers' awareness (Lee, Summers & Garza, 2009).. On the other hand, the result on the teachers' belief about ICT integration in education might not be sensitive to change because the lack of real world experience (Richardson, 2003). Pre-service teachers should be given the opportunities to practice teaching with technology in all teacher education courses and filed experiences (Mims et al., 2006).

5. Conclusion

This paper reported on the use of case-based learning approach to foster pre-service STEM teachers' TPACK competency. In a case-based ICT module, the pre-service STEM teachers have been transformed their TAPCK competency in STEM teaching and changed some of their belief about ICT in education. In an effort to better serve the needs of high quality STEM teachers, the results of this study illustrated that the competency of TPACK could be particularly considered as a core attributes for future STEM teachers. By the way, case-based learning approach can play an effective part in preparing and professing the TPACK competency for STEM teachers.

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