Research Article

ENHANCING PRESERVICE STEM TEACHERS' STEM PCK AND TEACHING SELF-EFFICACY THROUGH STEM PCK-BASED COURSE WITH THE USES OF EXPERIENTIAL LEARNING COUPLED WITH WORKED EXAMPLE INSTRUCTIONAL PRINCIPLES

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Skonchai Chanunan[1*]

[1]Faculty of Education, Naresuan University, Phitsanulok 65000, Thailand

*Corresponding Author, E-mail: skonchaic@nu.ac.th

Abstract

Preparing preservice STEM teachers who have very limited teaching experience for such a very challenging job needs specific requirements. The purposes of the study were to develop the STEM PCK-based course using experiential learning coupled with worked example instructional principles and then to examine the impacts of the course on preservice STEM teachers' STEM PCK and teaching self-efficacy. A convergent parallel mixed-methods design was employed in order to achieve comprehensive views of how the STEM PCK-based course impacts preservice STEM teachers. One of graduate courses was specifically developed and then implemented with 25 participating preservice science and mathematics teachers for 15 weeks in the first semester of 2016 at the Faculty of Education, Naresuan University, Thailand. For data collection, the writing test of STEM PCK conceptions and the STEM teaching self-efficacy instrument was developed and used with all participants as a part of quantitative data collection. While documentary analysis technique, the observation form, individual semi-structure interview with, and focus group discussion were also used in the qualitative part. For data analysis, a paired sample t-test was used along with basic descriptive statistics for quantitative data while content analysis technique was also employed for qualitative data. Drawn on both data, it is found that the developed STEMPCK-based course has positive impact on preservice STEM teachers' STEM PCK and teaching self-efficacy. The qualitative data also reveal that direct and reflective experiences of STEM teaching and learning are very important for preservice teachers in developing their STEM teaching knowledge and confidence as assisting in making sense of STEM teaching experiences. They also recognize and value available supports and guidance along with opportunities for reflection and discussion with others. This study has provided teacher educators and STEM education community with promising and very useful information about ways to equip preservice teachers with educative tools for STEM education.

Keywords: STEMPCK-based Course, STEM PCK, STEM Teaching Self-efficacy, Experiential Learning, Worked Example, Preservice STEM Teachers

Introduction

Recently, Thailand has been driven into economic and social reform with an expectation of prosperity, security, and sustainable development by being associated with the principle of sufficiency economy through various kinds of strategies such as the 20-year National Strategy (2017–2036), Thailand 4.0 Strategy, the National Sustainable Development Goals, etc. Among those, the new model of the education system is known as Education 4.0 has also been established in order to improve all the facets of education system. This educational model focus has been put more on personalized learning to bring out the best talent and competence from each learner and to get learners trained to be skillful. Currently, there are high demands in highly skilled and knowledge employees for various kinds of works in many companies or organizations. The report by Winley and Wongcuttiwat (2012), for instance, suggested that most companies and organizations in Thailand predicted to have more demand for workforces who are required to have deep skills and an extensive scope of roles with the ICT literacy and usage. In short, it is required that all the educational parts in Thailand must sharpen their curricula and training strategies. When considering the key strategies of the 12th plan, Thailand 4.0 strategy and Education 4.0 strategy, it is noticed that there are main emphases that have been put on human development and promoting the research and development for innovation and these kinds of progress and advancement require the essential prerequisites called quality educational system, especially STEM education, in order to improve competitive position. Accordingly, it is believed that economic and social benefits of STEM education have broad application for workforces in STEM and non-STEM careers (Gonzalez & Kuenzi, 2012).

For driving STEM education to succeed, preparing STEM teachers for such a work is the very first step to be taken. Ejiwale (2013, p. 65) suggested that being equipped with deep content knowledge in STEM and strong pedagogical skills for teaching their students are the two essential attributes that STEM teachers should possess to be able to help students achieve deep understandings of STEM for later utilization in their lives and careers. For being STEM teachers, in attaining deep science and mathematics content knowledge, earning a subject-specific degree has a positive effect on student achievement in both mathematics and science (Goldhaber & Brewer, 1998). Besides, for being competent in STEM teaching, teachers should be motivated to participate in professional development to help them achieve deep STEM content knowledge and mastery of STEM pedagogy. In so doing, developing a conceptual framework for STEM education in STEM teachers requires a deep understanding of the complexities surrounding how people learn, specifically teaching and learning STEM content. Kelley and Knowles (2016, p. 3) suggest that building a strategic approach to integrating STEM concepts by teachers requires strong conceptual and foundational understanding of how students learn and apply STEM content. Research shows that STEM education teaching is enhanced when the teacher has sufficient content knowledge and domain pedagogical content knowledge (Nadelson et al., 2012). As a result, professional training and curriculum or teacher education program for STEM teacher preparation should emphasize both STEM content knowledge and STEM teaching and learning strategies.

Among the key movements in Thai STEM education are teacher training and preparation for STEM teaching and learning. The Institute for the Promotion of Teaching Science and Technology (IPST), the Thai national organization in charge with science, mathematics and technology education, has established the national and regional STEM education centers throughout the country to launch and implement STEM teaching training and workshops. Even though there have been many workshops and training with in-service teachers across the country, few research studies have been conducted to find out the impacts of such training and preparation on the trained teachers and students in classrooms. Currently, there has been an increasing number of research studies being conducted with in-service teacher training and preparation for STEM education. These studies generally examined students' learning from STEM activities while research on teachers' knowledge and skills of STEM teaching and learning remains very few. Moreover, those training and preparations mainly focus on preparing in-service teachers whereas preservice teacher preparation, on the other hand, seems to be overlooked. Thus, what remains unprecedented in Thailand is the research on preparing preservice teachers for STEM teaching and learning, especially research on preservice teachers' knowledge of STEM teaching and learning.

In preparing STEM teachers, teachers ' knowledge for STEM teaching and learning is very important and fundamental for this kind of movement of STEM education. As teachers' knowledge in a form of Pedagogical Content Knowledge (PCK) plays an important role in any classroom instructions, similarly, teachers' knowledge for STEM teaching and learning also plays an important role in STEM classrooms. Thus, for preparing teachers for STEM education, teachers' knowledge for such a teaching job is vital. In the present study, the focus was placed on teachers' knowledge for STEM teaching and learning as a form of STEM PCK.

From the ideas suggested previously, it implies that teacher education program, especially for science and mathematics teachers namely STEM teachers, should emphasize on building and fostering strong foundation knowledge of STEM teaching and learning. As such, building preservice teachers' essential knowledge and skills such as STEM pedagogical content knowledge or STEM PCK of STEM teaching and learning and their STEM teaching self-efficacy is one of the very first steps in preparing preservice teachers for driving STEM education. However, preparing preservice teachers having very limited teaching experiences for such a very challenging job of teaching STEM needs specific requirements which are different from those in schools with much teaching experience. Hence, there is a strong need for preparing new coming STEM teachers in particular ways which they can gain their STEM teaching knowledge, STEM PCK, and capability to confidently plan and implement their STEM lessons effectively.

Literature Review

To set up the framework of the study, key conceptual understandings such as STEM education, STEM PCK, STEM teaching self-efficacy, experiential learning and worked example are reviewed and discussed, respectively. Consequently, the conceptual framework of the study was obtained.

STEM Education

The idea of science, technology, engineering, and mathematics (STEM) education has been conceptualized and developed by education community and any other groups interested in. STEM is the acronym for Science, Technology, Engineering, and Mathematics and these four letters represent the different areas of STEM education.

For the definition of STEM education in the present study, as drawn on Morrison (2006) and Tsupros et al. (2009), STEM education can be loosely defined as an integrated approach to learning that provide students with authentic real-life learning experiences where they can conceptualize context – related knowledge and skills and simultaneously make uses of their higher-ordered thinking skills and knowledges form various fields consisting of science, mathematics, technology and engineering in particular situation required them to take actions on developing innovation or solution to the problematic incidents. In addition, as STEM education, it is expected that well-integrated instruction provides opportunities for students to learn in more relevant and stimulating experiences, encourages the use of higher level critical thinking skills, improves problem solving skills, and increases retention (Stohlmann et al., 2012).

From the definition of STEM education and its implication for STEM classroom practices, STEM teaching and learning at school level, both at primary or secondary levels, is not simply bringing such STEM concepts to students but it should be conducted in such ways that teachers confidently, and forcefully, plan and implement STEM lessons which students are provided with authentic experiences, leading them to deeper understandings of all relevant knowledge and higher-ordered and any other related skills, including 21st century ones. As such, the teacher role in integrated STEM learning is to help students make abstractions and to decontextualize concepts for application in a variety of different real-world, authentic contexts (Moore et al., 2014).

Teacher' knowledge for STEM teaching and learning as STEM PCK

In the present study which is involved with preparing preservice teachers for STEM teaching, teachers' knowledge is framed and guided by Shulman (1986)'s pedagogical content knowledge or PCK model of teacher knowledge. In addition, some current ideas that are related to PCK, such as TPACK (technological pedagogical content knowledge), are also discussed.

Currently, there has been a widely accepted theoretical model of pedagogical content knowledge (PCK) developed by Shulman (1986). Shulman proposed that PCK is the knowledge which is developed by teachers to help others learn. Teachers develop their own PCK as they teach specific content or topics in their subject matter knowledge area. Geddis (1993, p. 675) also similarly added that teachers' PCK is the knowledge of transformation of subject matter knowledge into forms accessible to the students being taught. Grossman (1990) PCK is influenced by the transformation of three other knowledge bases: subject matter knowledge, pedagogical knowledge, and knowledge of context, which formalized as the knowledge about community, schools and students' background that teachers used in their classroom instruction. Those three kinds of teachers' knowledge together influence and are translated by teachers' PCK into their teaching in a particular subject and situation. For science teacher knowledge in particular, Magnuson et al. (1999) suggested that PCK consist of five components: 1) orientations towards science teaching which include a teacher's knowledge of goals for and general approaches to science teaching; 2) knowledge of science curricula, including national standards and specifics science curricula; 3) knowledge of assessment for science, including what to assess and how to assess students; 4) knowledge of science instructional strategies, including representations, activities, and methods; and 5) knowledge of student science understanding which includes common concepts and areas of difficulty. The PCK model has formed the theoretical framework for much research on science teacher knowledge and it is believed this model can also be used as a theoretical framework for research on teacher knowledge for STEM education.

Recently, the idea of Technological Pedagogical Content knowledge or TPACK has been introduced. This model was developed by educational researchers Mishra and Kohler (2006) and it is designed around the idea that content (what to teach) and pedagogy (how to teach) must be the basis for any technology that you plan to use in your classroom to enhance learning. In their TPCK teacher knowledge model, Mishra and Kohler (2006) elaborated teachers' technology knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and the concluding technological pedagogical content knowledge (TPCK), in addition to Shulman's PCK model. More recently, Saxton et al. (2014) proposed STEM pedagogical content knowledge or STEM PCK construct definition as a part of the STEM common measurement system. According to the proposed system, the STEM pedagogical content knowledge construct definition is composed of three parts: 1) Teachers' knowledge of student thinking about specific STEM topics including prior knowledge, misconceptions, learning progressions, common difficulties, and developmentally appropriate levels of understanding, 2) teachers' understanding and use of the effective strategies for specific STEM topics including strategies to engage students in inquiry, represent STEM phenomena, and guide discourse about the STEM topic, and 3) teachers' integration of technology to enhance instruction of specific STEM topics in meaningful and appropriate ways to promote key student college and career Readiness outcomes (p. 24).

From the notions of PCK and TPACK and the purpose of the present study, the five components of PCK by Magnusson et al. (1999) and Mishra and Kohler (2006)' TPACK were combined with the notion of STEM pedagogical content knowledge of the STEM common measurement system by Saxton et al. (2014). These notions were used as a guideline for developing the PCK conceptions of STEM teaching and learning as a construct and representation of teacher knowledge for STEM teaching and learning in the present study in particular. As thus, teacher knowledge for STEM teaching and learning was developed and used as a form of STEM PCK of STEM teaching and learning. In term of its definition, as drawn from the notions from Magnusson et al. (1999), Mishra and Kohler (2006) and Saxton et al. (2014), the STEM PCK of STEM teaching and learning is defined as a teacher's pedagogical content knowledge used for STEM teaching and learning which consist of seven components. The details of each component are presented in Table 1.

Table 1 The components of STEM PCK of STEM teaching and learning

Components	Descriptions
1. Definition of STEM education	Teachers' knowledge about definitions and key aspects of STEM education which include its meaning of integrated nature of STEM, learning goals of higher order thinking and 21st century skills, real world-related instructional methods, authentic assessment
2. Orientations towards STEM teaching	Teachers' knowledge and beliefs about purpose and goals for STEM teaching and learning. Belief about teaching approach or philosophy used by teachers for STEM teaching and learning.
3. Knowledge of STEM curriculum	Teachers' knowledge of curriculum goals and objectives for students' learning of concepts across STEM disciplines. Knowledge about instructional activities and materials used for helping students learn.
4. Knowledge of students' STEM learning	Teachers' knowledge and belief about students' prior knowledge, specific topic conceptions, learning difficulties (in specific content areas of STEM), misconceptions (in particular STEM topics), motivation, diverse in abilities and learning styles, interest, need, etc. In short, teacher knowledge on how student learn in STEM.
5. Knowledge of STEM instructional strategies	Teachers' knowledge about content subject-specific teaching strategies and integrated STEM approach used for STEM teaching. This is associated with orientations towards STEM teaching. In short, teachers 'knowledge on how to teach integrated STEM, such as knowledge about teaching approach, i.e., PBL, Engineering design process, inquiry, PjBL, etc.
6. Knowledge of technology integration into STEM instructional strategies,	Teachers' knowledge about technologies and how can make suitable and effective uses for students' learning in STEM activities according to specific STEM topics and teaching approach used. Knowledge about proper technology integration into STEM teaching and learning in which technologies can be used to facilitate STEM learning.
7. Knowledge of students' STEM learning assessment	Teachers' knowledge about assessment of students' STEM learning. Knowledge about identifying students' learning objectives in STEM, based on curriculum standards, and choose assessment strategies and instruments that are valid and appropriate for STEM content and related higher-ordered thinking skills. Knowledge about giving constructive and frequent feedback to students on their learning for their learning improvement.

These components of STEM PCK of STEM teaching and learning represent teachers' knowledge in terms of conceptual and procedural knowledge on how to teach STEM. The STEM PCK were developed and used as a frame to guide the present study.

STEM teaching self-efficacy

According to teacher belief system, in addition to teacher knowledge and skills, self-efficacy as one of the teacher belief system components is also important for teachers in teaching practices. For preservice teacher who want to teach STEM, teaching self-efficacy is considered one of the most important components in their belief system that can be built early during teacher education programs. In addition to STEM PCK, teachers' STEM teaching self-efficacy is also studied as STEM PCK, STEM teaching practices and STEM teaching self-efficacy are interrelated.

Teacher self-efficacy is generally referred to beliefs about teachers' ability to successfully implement instructional strategies. It has been identified in several studies as a major component in the instructional decision-making process for teachers. Lumpe et al. (2000), for example, outlined the multiple contributions that emerge from the possible interactions of content and efficacy beliefs and showed that decisions about practice are influenced by the relative weights of the components of the belief system. Many research studies indicate that teaching efficacy is complex construct influenced by a number of variables. Desouza et al. (2004), for instance, examined teachers' efficacy and found that teachers who held science degree and spent more time teaching science each week tended to have higher teaching efficacy. Interestingly, teachers with more experience were less confident of their students' achievement than those teachers with less experience. There is research evidence that teachers who lack confidence about teaching a subject will give in minimal emphasis within the curriculum. Woolfolk and Hoy (1990) suggested that teaching efficacy, in general sense, is related to teachers' experiences managing and motivating students. Furthermore, beginning teachers' success or failure in acting on their beliefs about student management may influence the development of sense of efficacy. They found that preservice teachers possessed teaching efficacy independently of personal efficacy. Personal efficacy included beliefs about responsibility for positive student outcomes and beliefs about responsibility for negative student outcome. In addition, there are some suggestions that students' responses to instructional practices can alter teachers' beliefs about teaching and learning science. Bandura (1986) suggested that for teachers to believe that change in instruction will make difference, teachers need to have feedback, experience success, observe models of success that are credible, and be persuaded that the concerns can be overcome with positive benefits. Bandura also suggested that affective feeling that arise from success will affect the teachers' self-efficacy.

In summary, teacher's self-efficacy is defined as a belief that is held by teachers about their abilities and competencies of instruction that can bring about students' desired learning outcomes in terms of engagement, motivation and learning, in STEM teaching in particular (Klassen et al., 2011; Tschannen-Moran & Hoy, 2001). Although, many research studies presented here are science teacher and science teaching-related, the findings from those studies are very promising and applicable to preparing preservice science and mathematics teachers for teaching STEM in the present study. As thus these implications are used as a guide for building the intervention for enhancing preservice STEM teachers' teaching self-efficacy.

STEM PCK-based course as incorporating instructional principles of experiential learning and worked example

In the present study, one of the courses in teacher education program of master's degree was used. The author, as a researcher, inquired and found very promising ideas of incorporating key instructional elements of experiential learning and worked example into one of the course of teacher education program to help preservice science and mathematics teachers conceptualize STEM PCK of STEM teaching and learning as well as gain their STEM teaching self-efficacy in order that they would be proficient STEM teachers and teaching their STEM lessons effectively.

According to the notions of experiential learning suggested by Moon (2004) and Linn et al. (2004), the key aspects of successful experiential learning consist of 1) reflection, critical analysis and synthesis, 2) opportunities for learners to take initiative, make decisions, and be accountable for the results, 3) opportunities for learners to engage intellectually, creatively, emotionally, socially, or physically, and 4) the lessons of learning experiences includes the possibility to learn from natural consequences, mistakes, and successes. With this kind of learning, learners are engaged in learning experiences that they see the relevance, then increase their motivation to learn and produce a more thoughtful product. To solve problems and complete tasks in unfamiliar situations in real context, learners need to figure out what they know, what they do not know, and how to learn it. As a result, this produce more autonomous learners. In addition, the reflection part of experiential learning deepens their learning and help them transfer their previous learning to new contexts, master new concepts, principles, and skills, and articulate how they developed their master.

In addition to experiential learning, some key instructional principles of worked examples were also considered and incorporated into the intervention of the present study. According to Clark et al. (2006), "a worked example is a step-by-step demonstration of how to perform a task or how to solve a problem" (p. 190). The focus of worked example is on that learners learn more efficiently and more robustly when they perform tasks or problem-solving practice with provided more frequent supportive study of worked examples. Renkl (2005); Renkl and Atkinson (2007) have additional suggestions that through instructional model of example-based learning, learners are able to gain a deeper understanding of domain principles when they receive worked examples at the beginning of cognitive skill acquisition because the examples give learners a clue on the right steps to solving the problem or performing the task.

The worked examples and examples used in the present study are different in many ways from general worked examples which students, in general, use during their learning to solve science or mathematics problems. As they are different in the context and content that were used, the examples in this study were provided in several forms and format to help preservice science and mathematics teachers learn how to teach STEM. In the present study, the instructional principles of worked examples were not merely used but it was critically chosen and employed for a particular context of teacher training and education by focusing on learning with examples. As such, the worked examples of STEM teaching and learning were set and distributed throughout the course in various forms such as examples of STEM lesson plans, examples of STEM teaching and learning activities, examples of STEM teaching VDO clips. With these various kinds of examples, preservice STEM teachers could learn how to teach STEM more effectively.

From the notions of experiential learning and worked example instructional principles previously discussed, it is strongly believed that for preparing preservice science and mathematics teachers for STEM teaching and learning, the preservice teachers should be provided with learning opportunities that they learn to take initiative, make decisions, and be accountable for the results by intellectually, creatively, emotionally, socially, or physically engaging in their tasks and also having opportunities of reflection, critical analysis and synthesis throughout their learning experiences. In addition, they should be provided with supports in the forms of worked examples at the very early steps of their learning to teach STEM as parts of and through their teacher education program in order that they would gain deeper understandings and be able to perform their STEM teaching effectively.

Research Questions, Purposes, and Hypotheses

The purposes of this present study were to develop an effective approach to preparing preservice STEM teachers for STEM teaching and learning for their future teaching career by incorporating key promising instructional principles of experiential learning and worked example into the selected course of teacher education program called STEM PCK-based course and also to examine the impacts of the developed course on their STEM PCK as well as their STEM teaching self-efficacy. As thus, there were two key research questions of the present study as follows: 1) what were the impacts of the STEM PCK-based course incorporating experiential learning and worked example instructional principles on preservice STEM teachers learning to teach STEM? and, 2) how did the STEM PCK-based course affect preservice STEM teachers learning to teach STEM in terms of their STEM PCK, STEM teaching self-efficacy and STEM teaching practices? Consequently, the hypotheses of the study were established as follows. Hypothesis 1) Preservice STEM teachers' STEM PCK knowledge after intervention was higher than that of before one according to pretest-posttest difference. Hypothesis 2) Preservice STEM teachers' STEM teaching self-efficacy after intervention were higher than that of before one.

Research Methodology

This study drew upon both quantitative and qualitative data as it used mixed methods research design. A specific design of convergent parallel mixed methods research was used to develop more complete understandings of the research problem by obtaining different but complementary data with legitimate validation (Creswell & Plano Clark, 2011). In addition, a one group pretest-posttest-design was also used as a part of the larger framework of the mixed methods research design to investigate the impacts of the STEM PCK-based course. With this research design, the assuring results of the study were obtained.

Context and participants

The present study took place during the time of the graduate course of 378514 organization of science and mathematics camp offered as part of the master's degree of teacher education programs at faculty of education, Naresuan University, Thailand in the first semester academic year. In this course, the student teachers explore fundamental understandings and processes of science and mathematics camp as well as implement their developed learning activities for various groups of primary and secondary level students in real situations of integrated learning camps at schools or some chosen learning places. For the purposes of the study intending to introduce STEM education into the course, additional knowledge and skills of STEM teaching and learning were provided in the course.

A total of 25 preservice science and mathematics teachers of master programs of education at the Faculty of Education, Naresuan University, Phitsanulok, the northern part of Thailand, consented to participate in the present study. All of them were enrolled in the course of 379514 Organization of Science and Mathematics Camps in the first semester of 2016 and this course was instructed by the author. The participants comprised four preservice mathematics teachers (two males and two females) and 21 preservice science teachers (eight males and thirteen females). For the preservice science teacher participants, six (two males and four females) were from master of education program in chemistry, ten (two males and eight females) were from master of education program in biology, and five (four males and one female) were from master of education program in physics. Their age ranged from 21 to 24 years (M = 22.56, SD = 1.02). All the participants were considered having very limited teaching experience. Before entering to the Master of Education Program, all of the participants were bachelor degree holders with various fields and had intention of having teaching license for their teaching careers in schools through the master program.

For the students participating in the two-day integrated STEM camp activities in two different schools involved in the study. For the secondary level camp, 56 9th grade students in one school at Bang Rakam, in Phitsanulok took part in the study while the primary level camp, 89 students from 5th, and 6th grade of one school in Phitsanulok participated in the study. Consent was obtained from all the students participating in the camp activities, the parents of the students and the school principals.

The Design of STEM PCK-based course by incorporating key instructional principles of experiential learning and worked example

Based on experiential learning suggested by Moon (2004) and Linn et al. (2004), mentioned above, direct learning experiences and reflective practices were used throughout the course such as inquiry-based experiential learning, class and group activities, hands-on experiential learning, experiential learning with reflection, etc. In addition, coupled with experiential learning, worked example instructional principles were also used. The examples of STEM teaching and learning, in the present study, were provided in various forms and used differently throughout the course. One of master courses was chosen and developed as the STEM PCK-based course for the present study. The designed learning opportunities of the course for preservice science and mathematics teachers was developed using the instructional principles of experiential learning and worked example. The course was divided into four parts and each part comprised distinct learning objectives and various learning opportunities. The key fundamental knowledge and skills and the learning opportunities and experiences in the course are presented in the following table.

Table 2 The overview of the course incorporating instructional principles of experiential learning and worked example

Part	Objectives	Knowledge and Skills	Learning Activities	Duration	Setting
1	- Develop key ideas of science or mathematics camp organizing process and implementation	- Key foundations of science or mathematics camp organization - Process of camp implementation	- Inquiry based experiential learning - Group works - Small group discussion	2 weeks (week 1-2)	Course classroom
2	- Develop basic knowledge about STEM teaching and learning	Definition of STEM education, Key aspects and related learning theories of STEM teaching and learning -Engineering ideas and practices - STEM teaching and learning approach and strategies, assessment for STEM learning	- Experiential learning based inquiries - Small group discussion - Experiential learning and learning from examples of engineering work - Hands-on experiences through two examples of STEM learning activities	3 weeks (week 3-5)	Course classroom
3	- Plan the integrated STEM camps for targeted students - Design, develop, and test the developed STEM activities	- Planning integrated camps for targeted students - Developing the STEM activities for camp settings - STEM lesson development skills - Assessment skills for STEM learning	- Group works with examples of STEM lesson plans and STEM teaching VDO clips developed by IPST YouTube channel - Experiential learning through reflection on testing the developed STEM activities after demonstration in course classroom - Discussion on STEM lesson design	6 weeks (week 6-11)	Course classroom
4	- Implement the integrated STEM camps	- Implementing the developed STEM lesson in camps	- Experiential learning through integrated STEM	4 weeks (week 12 -15) Implementing	Camp activities in schools

Part	Objectives	Knowledge and Skills	Learning Activities	Duration	Setting
	- Develop STEM teaching skills - Develop STEM learning assessment skills	- STEM Teaching and managing skills - STEM learning assessment skills	camp implementation at assigned schools - Reflection on implementing STEM activities	two-day camps in week 12 & week 14 in two different schools	+ Course Class

Based on the instructional principles of experiential learning and worked examples, various kinds of experiential learning of STEM teaching and learning activities were developed and provided as well as the examples of STEM teaching and learning. The examples used in the present study are different in many ways from general worked examples which students, in general, use during their learning to solve science or mathematics problems. As they are different in the context and content that were used, the examples in this study were provided in several forms and formats to help preservice science and mathematics teachers learn how to teach STEM.

In addition, in order for the preservice teachers to experience and gain understandings about engineering ideas and its professional practices, the author as the main instructor of the course invited an engineering instructor from faculty of engineering from the same university to be as a co-instructor of the course. Moreover, throughout the course, the preservice teachers had chances to interact with the invited engineering instructor for guidance and suggestion while they worked on developing their STEM lessons and also implementing the STEM activities in the student camps.

Data collections

According to the mixed methods research design employed, various quantitative and qualitative research tools and instruments were developed and used for the present study. The quantitative research instruments consisted of 1) the writing test on STEM PCK of STEM teaching and learning, and 2) the STEM teaching self-efficacy instrument. Whereas documentary analysis technique, the observation form, the question set for individual semi-structure interview, and the leading questions focus group discussion were also used in qualitative part. The development of research tools and instruments are described as follows.

Quantitative data collection

For quantitative data collection, there were two kinds of research instruments consisting of 1) the writing test on PCK conceptions of STEM teaching and learning and 2) STEM teaching self-efficacy instrument. For the writing test, the test on STEM PCK along with its scoring rubric was created using the notions of five components of teachers' PCK developed by Grossman (1990) and combining with the notion of STEM pedagogical content knowledge of the STEM common measurement system by Saxton et al. (2014). Draw on these notions, seven key question items of the writing test along with scoring rubrics were obtained. The writing test draft was sent to five STEM experts for checking content validity. Through using IOC (index of congruency) for checking content validity by the experts, the questions of the writing test have their validity range of 0.60 – 1.00, making the writing test valid for the study. For the reliability of the test, the developed writing test was trialed out with 21 science and mathematics master students who were not in the study group and already took the course in the previous year and had experiences of STEM teaching and learning. The writing test was conducted twice in a four-week time period difference in order to find test-retest reliability. After completing the test, each student's responses of the writing test were checked and scored by the author using the scoring rubric. For avoiding bias, another one experienced STEM teacher was also involved in checking and scoring students' responses of the writing test. After that, as for the purpose of finding test-retest reliability, the two sets of students' writing scores were taken for being calculated through SPSS 20 for windows software using Pearson correlation coefficient. It was found that the writing test has good reliability of 0.81. As a result, the developed writing test was valid and reliable and could be used in the present study.

In developing the STEM teaching self-efficacy instrument, the notion of the Teacher Sense of Self Efficacy (TSES) Survey developed by Tschannen-Moran & Hoy (2001) was adapted and adopted for the present study. The items of the STEM teaching self-efficacy instrument covered three key aspects of STEM teaching efficacy: 1) efficacy for instructional strategies, 2) efficacy for classroom management, and 3) efficacy for student engagement. A 5-rating Likert scale was used for each item. For the validity and reliability of the instrument, the process was run the same as the writing test. As a result, the STEM teaching self-efficacy instrument (with total 22 items in three different aspects) with validity of 0.6 to 1.0 range and Cronbach's alpha coefficient of 0.92 was obtained.

In collecting quantitative data, the writing test was administered to all 25 preservice science and mathematics teachers before and after the course. For checking and scoring the preservice teachers' responses to the writing test, the same process used in finding the test-retest reliability was conducted by the author and one experienced STEM teacher. For examining the participants' STEM teaching self-efficacy, the STEM teaching self-efficacy instrument was administered three times during semester: before, in the middle and after the course. For before and after the course, the STEM teaching self-efficacy instrument was administered in the same day with the writing test. Whereas for in the middle examination, the participants took the STEM teaching self-efficacy instrument one week prior to implementing the STEM camp activities with students.

Qualitative data collection

For the qualitative part of data collections, there were various tools and methods employed such as documentary analysis, observation, individual semi structured interview and focus group discussion. For those data collecting methods, some additional research tools were developed such as the discussion topics for individual semi structured interview and focus group discussion. The discussion topics and observation form were framed around and in line with the notions of teachers' PCK by Grossman (1990) and STEM PCK by Saxton et al. (2014), already used in developing the writing test. Moreover, multiple data sources such as the STEM lesson plans, students' worksheets and related learning materials for students in the camp activities developed by the preservice teachers were also used in documentary analysis. All qualitative tools and methods were developed in consultation with and checked for their validity by the same group of the experts throughout the study. In collecting qualitative data, the discussion topics were used in focus group discussions of two groups of six preservice teachers (twelve in total) after the course finished in the final week of semester. In addition, the discussion topics were also used in individual semi-structured interviews with eight selected preservice teachers according to their responses in the writing test after conducting focus group discussion.

Data analysis

For quantitative data analysis, appropriate statistics was purposely chosen and used for hypothesis testing. In addition, basic descriptive statistics were also used. While content analysis technique was employed as the main qualitative data analysis approach in analyzing all the obtained qualitative data. Details of each approach are described as follows respectively.

Quantitative data analysis

As the study purposes were to find the difference between before and after intervention of the same group of the participants, the paired sample t-test statistics, therefore, was used to determine the extent to which the preservice teachers had significant improvement of STEM PCK and self-efficacy on STEM teaching and learning from pretest to posttest. As the matter of fact that using paired sample t-test statistics for the present study may not fit with the requirement of this kind of statistics. However, in order to apply this paired sample t-test statistics, the test of normality was used for checking normal distribution to assure that this t-test was applicable for the present study. With the use of Shapiro-Wilk W- test developed by Shapiro and Wilk (1965), it was found that the result of the Shapiro-Wilk W-Test

(P = 0.563) were statistically insignificant, as a result, the data were normally distributed. This means that the paired sample t-test could be applied for the study.

For the statistics analyses, the Alpha-level was set at $p < .05$ in using the paired sample t-test. Descriptive statistics, such as mean and SD, were used to illustrate the aspects of STEM teaching self-efficacy in three different assigned periods of times of data collection over the course: before, during and after the intervention.

Qualitative data analysis

In analyzing process, Bengtsson' s (2016) four main stages of qualitative content analysis, was used. In the stage one, *decontextualisation*, all the transcribed text sets of the data were checked and read through out by the author to get whole view of the happenings and then were broken down into smaller meaning units containing some insights or aspects answering the questions or topics framed around the research purposes. Then, the meaning units were labeled with codes that can be understood accordingly to the context, as a part of open coding process (Berg, 2001). After identified, the meaning units with their codes were then checked if they were covered and related to the research questions and purposes in the stage two, *recontextualisation*. Then, in the stage three, *categorization*, the categories were created by the author. Then, themes and categories were carefully identified. Sub-categories and sub-themes were also sorted. At the last stage, *compilation*, the author started to analyze the obtained data and the results were generated and written down according to the themes and categories already established. To obtain high quality research and best validity of the present study, the author and another one experienced assistant researcher performed data analysis independently. After the separated data analyses were finished, all the analyzed data were taken into decisive discussion between the author and the assistant researcher to check the similarities and differences in order to reach consensus (Graneheim & Lundman, 2004). This process was performed for the purpose of and as a form of triangulation. In addition, the developed themes were sent back to the participants for member checking and verifying.

Results and Findings

The presentation of results and findings is organized around the research questions and purposes. Both analyzed quantitative and qualitative data were presented in parallel and combined.

Impacts of STEM PCK-based course incorporating instructional principles of experiential learning and worked example on STEM PCK

The improvement in STEM PCK was inspected by using pretest and posttest scores from the writing test. Then, the scores were statistically calculated and shown in the following table.

Table 3 Comparison of the preservice STEM teachers' STEM PCK mean score between after (posttest mean) and before (pretest mean) the intervention in overall

Score	N	df	M	SD	t-test	α
			(Total score = 28)			Sig (1-tailed)
Pretest	25	24	5.88	1.33	18.89*	< 0.05
Posttest	25	24	22.38	2.89		

$^{*}T_{(0.05,\ df\ 24)} = 2.06$ df = N-1

From the Table 3, a paired sample t-test was conducted to compare STEM PCK before and after the intervention. As a result, there was a significant change from before the intervention (M = 5.88, SD = 1.33) and after the intervention (M = 22.38, SD = 2.89) conditions; t (24) = 18.89, P = 0.05. In addition, in order to investigate specifically each component of the STEM PCK, the separate mean scores in each component were also used in conducting a paired sample t-test to find the difference between before and after the intervention. The results of each component comparison are presented in the following table.

Table 4 Comparison of the preservice STEM teachers' STEM PCK mean score between after (posttest mean) and before (pretest mean) the intervention in each component

Components of STEM PCK of the study	Pretest M (SD) (total score = 4)	Posttest M (SD) (total score = 4)	t-test	α Sig (1-tailed)
definition of STEM Education	1.0 (0.71)	3.44 (0.56)	9.55*	< 0.05
orientations towards STEM teaching	0.52 (0.50)	3.00 (0.64	8.87*	< 0.05
knowledge of STEM curriculum	0.68 (0.62)	3.32 (0.63)	11.76*	< 0.05
knowledge of students' learning	0.76 (0.58)	3.00 (0.41)	8.52*	< 0.05

Components of STEM PCK of the study	Pretest M (SD) (total score = 4)	Posttest M (SD) (total score = 4)	t-test	α Sig (1-tailed)
knowledge of STEM instructional strategies	0.96 (0.49)	3.25 (0.60)	9.03*	< 0.05
knowledge of technology integration into STEM instruction	0.96 (0.49)	3.16 (0.55)	10.19*	< 0.05
knowledge of students' STEM learning assessment	0.86 (0.51)	3.24 (0.60)	11.55*	< 0.05

*$T_{(0.05,\ df\ 24)}$ = 2.06 df = N-1

According to the calculation, there were significant changes in all components of STEM PCK after the intervention. All changes were statistically significant.

Impacts of the STEM PCK-based course incorporating instructional principles of experiential learning and worked example on STEM teaching self-efficacy

The mean scores from before and after intervention were used in a paired sample t-test calculation to find the change in STEM teaching self-efficacy. In addition, the three aspects of STEM teaching self-efficacy were also separately analyzed and compared over the course. The results of STEM teaching self-efficacy are presented in the following Table 5 and Figure 1 respectively.

Table 5 Comparison of the preservice STEM teachers' STEM teaching self-efficacy mean before and after the intervention

Score	N	df	M	SD	t-test	α Sig (1-tailed)
Before (1^{st} week)	25	24	1.26	0.68	8.98*	< 0.05
After (Last week)	25	24	3.38	0.64		

*$T_{(0.05,\ df\ 24)}$ = 2.06 df = N-1 Note. Means are based on 5-point scales. 1= very low. 5=very high

Referring to Table 5, it can be seen that there is a significant change from before the intervention (M = 1.26, SD = 0.68) and after the intervention (M = 3.38, SD = 0.64) conditions; t (24) = 8.98, P = 0.05. The result indicated that there was a statistically significant change and strong positive impact on preservice STEM teachers' STEM teaching self-efficacy from the intervention.

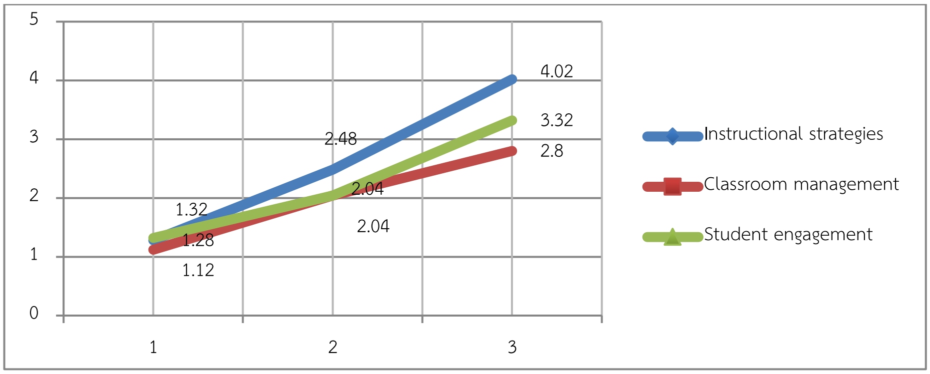

Figure 1 Mean scores of STEM teaching self-efficacy in each aspect over the course. On the x axis of the graph, 1 is referred to before, 2 is referred to during and 3 is referred to after the intervention. Means are based on 5-point scales. 1= very low. 5=very high.

As can also be seen in Figure 1, there was a change over the time from before, during and till after the intervention as the graphs showed an improving trend in all aspects of STEM teaching self-efficacy. The changes of all aspects appeared liner and were similar. However, the greatest change was found on the aspect of instructional strategies (4.02, SD = 0.58) and the smallest change was found on classroom management aspect (3.32, SD = 0.56).

Results and findings from supporting qualitative data

To get more comprehension about how the course impact the preservice STEM teachers' STEM PCK and their confidence of STEM teaching, the results and findings from qualitative data analysis are presented and discussed. According to the data, five emerging themes associated to how the STEM PCK-based course impacts the preservice STEM teaches' STEM PCK and their STEM teaching self-efficacy are explored.

Engineering ideas and practices are an essential knowledge. According to the data obtained, it was revealed that understandings and experiences about engineering ideas and practices were very useful for preservice teachers in terms of understanding the integrated nature of STEM education. All the participants of focus group discussion and semi-structure individual interview had similar comments on the importance of understandings of engineering ideas and practices. One of the selected participating preservice science teachers commented about interacting with engineering activities in class:

"Learning and experiencing with examples of engineering design process activities and seeing how engineering work helped me look and had a clearer picture about how STEM could go in classroom teaching

with students. I saw the links where science and mathematics could meet in engineering as science and mathematics could be thought as knowledge used for constructing things in engineering." (PST3)

Supports and guiding are very important while learning to teach STEM from examples. Most of the participating preservice science and mathematics teachers mentioned about a necessity of supports and guidance during learning and working with the examples. As one preservice mathematics teacher commented that:

"Guiding questions given before and critiquing activities after watching the VDO clips were very good for me. This helped me see what to do in what way. I liked key essential questions used to guide us what to see during watching the examples of the STEM teaching VDO clips." (PMT4 from semi-structure individual interview)

Collaboration between preservice science and mathematics teachers. According to the data obtained, preservice STEM teachers all reflected that working with peers from different disciplines was very useful in terms of helping them understand the integration of STEM education as the nature of integration of the STEM curriculum. Preservice science teachers highlighted the benefits of working collaboratively with preservice mathematics teachers in ways that they got better view to understand how to obtain the standards of mathematics from the curriculum during developing the STEM lesson plans. In addition, all the participants from focus group discussion also indicated that clarification and explanation from different perspectives help them understand and view STEM teaching and learning differently from what they had seen before and got them a clearer picture about STEM education.

Direct learning and teaching STEM experiences with reflections and feedbacks. According to the data from interview and focus group discussion, most of the participants mentioned about their understandings of how students learn in STEM activities in the camps. They expressed that implementing their STEM lessons with students in the camps allowed them to have chances to do actual teaching and to interact with students. They added that during the STEM activities, interacting with students by asking questions, guiding students in the activities, giving learning supports and getting feedback, helped the preservice teachers understand more about how students learn in STEM activities. They could encounter students having difficulties in learning and making understanding key related science and mathematics concepts of STEM activities and tried to find ways to help students understand those concepts before moving to the next steps. Many preservice teachers also similarly commented about getting more understanding about students' learning in STEM activities from implementing the STEM lesson that they had developed. For examples, one preservice science teachers stated that:

"I think teaching our STEM lessons with real students in the camps was very beneficial for me or even others because I had chances to interact with students. I provided them with learning resources and supports during the activities and also checked them quite often to see if they got to the point we intended. Sometimes, I found that they did not understand what we were trying to get them understand and I think some of students during the activities had difficulties understandings the concepts [science concepts of STEM activities]. And this took us a little while to find ways to help them understand those concepts" (PST4-semi-structure individual interview)

In addition, most of the preservice teachers also mentioned about experiencing both learning in STEM activities through student's role and implementing the camps and teaching STEM lessons as teachers with real students helped them get deeper understanding about how students learn in STEM activities and, as teachers, how to help students learn STEM successfully. The data also revealed that self-reflection, peer reflection, instructor's reflection and students' responses and feedbacks are very important part for their STEM teaching.

Connection of and translation from examples to actual STEM teaching. Draw on the obtained qualitative data, it was revealed that preservice teachers made connection between what they learned from the various kinds examples and their actual STEM teaching experiences and this connection helped them see better and clearer views of how to teach STEM. As preservice teachers replied on a question seeking for what preservice teachers could gain from learning with examples and teaching STEM with real students, many of them highlighted the connection between learning the examples in classroom and having chances develop and teach their own STEM lesson as referred to theory into practice. One preservice science teacher, for instance, explained that:

"At the very beginning of the course, I just knew that I would teach the integrated lessons of science and mathematics as the requirement of the course and I also knew what STEM was…BUT…Ahhhh… I did not really know what to do and how to do it [teaching STEM]. When we learned various kinds of examples of STEM teaching and learning such as learning examples of STEM activities through the roles of students, reading examples of STEM lessons, watching examples of STEM teaching VDO clips, I felt that I understand it [teaching STEM] but I was not sure that much. However, with reflections during our STEM teaching practices and implementation of developed STEM lessons with real students, I came to realize that what I learned from many examples [of STEM teaching and learning] really did come to an action and I

could use them [knowledge of STEM teaching and learning] at that day in the camps with students. Even though, at those days [STEM camps], we were not that good, but we had tried our best and learnt so much." (PST5 from semi-structure individual interview)

Discussions

Impacts of STEM PCK-based course incorporating instructional principles of experiential learning and worked example on STEM PCK

In examining preservice STEM teachers' STEM PCK, it was found that there were significant changes in all components after the intervention. In discussing the results, learning through interacting with the various forms of examples of STEM teaching and learning with supports and guidance is one of the key learning processes that helped preservice teachers in learning to teach STEM effectively as they gained deeper understandings about STEM teaching and learning. This result corresponds to previous research on worked-example effects which suggested that learning by studying worked examples is more effective than problem solving or performing tasks without any kind of support (Schwonke et al., 2009). The present study also showed positive impact of using example-based learning for novices' learning as preservice science and mathematics teachers with very limited teaching experiences, in the study, were considered as novices in learning to teach STEM. This was believed that it, otherwise, would have taken longer or even got them difficulties if they tried to discover about how to teach STEM without any kinds of helps. The present study result also concurs with work by Tuovinen and Sweller (1999) as in their study they found that worked example-based instruction was more beneficial for novices than discovery-based learning. Besides, one interesting theme emerged from supportive qualitative data is that understanding about engineering ideas and practices can help preservice teachers better understand STEM teaching and learning. As the preservice STEM teachers were provided with learning opportunities to experience engineering process and practices as a part of the course, they interacted with examples of engineering work and activities as well as interaction with the invited engineering instructor. Through this kind of experience, the preservice teachers found that this understanding helped them view STEM teaching and learning in a better position, knowing about the integrated nature of STEM education and shape how they view STEM teaching and learning with better understandings about aspects of STEM curriculum. This reflects the importance of integrative nature of STEM education through the view of engineering and this can be considered as key knowledge component of STEM PCK for the preservice teachers.

In addition, collaboration between preservice science and mathematics teachers is considered as one of the key factors that affect preservice teachers' STEM PCK when learning collaboratively in experiential learning setting. Working with teachers with different backgrounds from different academic fields can help teachers have better understandings about STEM teaching and learning, understanding about the integrated nature of STEM education in particular, as they work across disciplines to help students learn in STEM activities. These findings are in consistency with the Rodgers’ notion (2002) that sharing ideas with others is a crucial component of making sense of and learning from experiences. This is also consistent with Northfield’s (1993) assertion that for preservice teacher programs, a program must consider the needs of teacher candidates and recognize that needs change as development occur and collaboration with other candidates is essential.

Direct learning experiences with examples of STEM activities in a student’s role allowed preservice teachers to understand how students would learn in STEM activities in terms of their difficulties learning particular topics or concepts of science and mathematics and difficulties in making connections among STEM in the STEM lessons. This helped preservice teachers gain understandings about students’ learning in STEM lessons as they experienced themselves previously and these experiences are very useful during teaching their own STEM lessons with students in the camps. Additionally, for reflection as a part of experiential learning, Dewey (1938) suggested that opportunities for learners to reflect on their experiences can assist them in creating continuity and meaning form those experiences and therefore an essential element of all educative experiences. As playing an essential role in experiential learning in helping preservice science and mathematics teachers learn to teach STEM, reflection processes were taught to preservice teachers and conducted in several and different times throughout in-class activities and as parts after the camp implementation of the course. In the reflection after teaching STEM as a group in the camps, preservice teachers had opportunities to reflect on their own STEM teaching as well as others for the purpose of helping each other to develop knowledge and practices of STEM teaching and learning. Consequently, with reflective practices, preservice science and mathematics teachers gained their understandings in term of STEM PCK as well as teaching self-efficacy, resulting from their experiential learning throughout the course. This supports Loughran’s (2002) notion that the possibilities for preservice teacher learning could be enhanced through effective reflective practice. Accordingly, the finding of the present study also concurs to Linn et al. (2004) who indicated that the reflection part of experiential learning deepens their learning and help them transfer their previous learning to new contexts, master new concepts, principles, and skills, and articulate how they developed their mastery.

As mentioned by several preservice science and mathematics teachers that they viewed students’ success in STEM learning during the camps and feedbacks very valuable as they perceived it as reinforcement that helped them see whether their STEM teaching work or not, this was considered as one of the important aspects that could be incorporated as part of reflective practices of their STEM experiential learning. This is similar to the notion suggested by Guskey (2002) that positive changes in students’ outcomes is one of the motivating factors for teachers to change their teaching practices. Moreover, making connection from learning with examples to actual teaching STEM lessons in the camps is also found to be one of the key mechanisms of preservice teachers learning to teach STEM. This finding is consistent with the notion which Dewey's (1938) used to describe a similar process as creating a continuity in learning, as learners interact with and make sense of their experiences to connect prior and present experiences in meaningful ways to learn particular ideas.

Impacts the STEM PCK-based course incorporating instructional principles of experiential learning and worked example on STEM teaching self-efficacy

As examining STEM teaching self-efficacy, the result indicated that there was a statistically significant change after the intervention, suggesting that the intervention had a strong positive impact on the preservice teachers' STEM teaching self-efficacy. In addition, through a closer look, it was found that there was a change over the time from before, during and till after the intervention as the graphs in Fig. 1 showed an improving trend in all aspects of STEM teaching self-efficacy. The changes of all aspects appeared liner and were similar. However, the greatest change was found on the aspect of instructional strategies and the smallest change was found on classroom management aspect. The results suggested that the intervention had a strong positive impact on the preservice teachers' confidence of teaching STEM on their instructional strategies aspect, while had a moderate impact on student engagement aspect and respectively had a lowest impact on their confidence of classroom management aspect in STEM teaching. With supports from the obtained qualitative data, it is clear that in overall preservice STEM teachers had developed their STEM teaching.

In discussing about the overall of an increased STEM teaching self-efficacy, as the preservice teachers experienced teaching their STEM lessons in the two-day camps with real students and had students' responses in terms of learning achievement and feedbacks, their confidence of STEM teaching increased. In their STEM teaching in the camps, they had direct experiences in managing and motivating students. Preservice teachers found that students succeeded as achieving learning objectives in learning through STEM lessons could reinforce confidence of their STEM teaching. The findings of the present study are similar to those of the case studies conducted by Palmer (2002) which reported that attitude and confidence could be changed as preservice teachers experienced success in their teaching. In addition, this result supports the notion suggested by Bandura (1986) that affective feeling that arise from success will affect the teachers' self-efficacy. Besides, as in this course, preservice teachers were also provided with supports and guidance throughout the course as discussed previously, the type of supports they receive may also affect their self-efficacy. Previous studies on preparing preservice teachers for STEM education in particular have been conducted and reported that preservice science teachers who participated in and received particular STEM education training and preparation improved their perceptions of STEM teaching efficacy and feeling comfort with teaching STEM (Nadelson et al., 2012). As can be seen, the findings of the present study are consistent with the that of the previous studies in terms of improving preservice STEM teachers' STEM teaching efficacy.

Conclusions, Recommendations, and Implications

Overall, the results and findings clearly indicate that the STEM PCK-based course using experiential learning and worked example instructional principles has strongly positive impacts on preservice STEM teacher's STEM PCK and their STEM teaching self-efficacy as the preservice teachers' knowledge and confidence of STEM teaching and learning significantly changed after they completed the course. The married data obtained from both quantitative and qualitative parts reveal that the combination of the two learning principles has synergistic effects on preservice teachers learning to teach STEM in ways that preservice science and mathematics teachers interact with and learn from various forms and formats of STEM teaching and learning examples with supports and guidance through direct and reflective experiences in collaborative learning environment between preservice science and mathematics teachers with an incorporation of engineering ideas and practices to help preservice teachers make meaningful connection which resulted in better view of and deeper understandings about STEM teaching and learning as well as confidence in STEM teaching.

For teacher education for STEM education, this study has provided promising and very useful information for teacher educators and STEM education community in terms of informing ways to empower and equip preservice science and mathematics teacher with educative tools for their STEM teaching and learning as will be parts of their teaching career in the near future. For further research, follow-up studies are needed to explore the possible long-term impacts when they teach STEM as beginning teachers in their classrooms at schools after graduation and also to examine how their STEM PCK is enacted. In-depth studies investigating individual preservice teacher's experiences of successes and difficulties in teaching STEM are also another area that need to be explored as they may suggest some guiding principles for teacher education community in terms of designing teacher education curricula in varied setting. With careful and systematic data collection and analysis from both qualitative and quantitative parts of the mixed methods approach employed, it is confidently argued that the results and findings can inform other teacher education programs promising ways to prepare preservice teachers for STEM education.

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