CO-TPACK: ENHANCING COOPERATION AMONG SCIENCE TEACHERS THROUGH TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE

Siriwan Chatmaneerungcharoen[1]

[1]Department Head of General Science, Faculty of Education, Phuket Rajabhat University, Thailand

Received: August 6, 2018 Revised: March 28, 2019 Accepted: March 29, 2019 Published Online: September 18, 2019

ABSTRACT

An emerging body of "21st century skills," such as adaptability, complex communication skills, technological skills, and the ability to solve non-routine problems, are valuable across a wide range of jobs in the national economy. Thai science education has advocated infusing 21st century skills into the school curriculum, and several educational levels have launched such efforts. However, developing proper knowledge among science teachers will be the most important factor in achieving goals related to these endeavors. The purposes of this study were to enhance 40 cooperating science teachers' and 48 pre-service science teachers' Technological Pedagogical Content Knowledge (TPACK) and to develop a Professional Development Model integrated with a Co-Teaching Model and Coaching System. Forty volunteer in-service teachers, or cooperating science teachers, participated in this study for 2 years. Data sources throughout the research project consisted of teacher reflections, classroom observations, semi-structured interviews, situational interviews, questionnaires, and document analysis. An interpretivist framework was used to analyze the data. Findings indicate that teachers did not initially know how to integrate the technology into their science classrooms. Mostly, they preferred using lecture-based teaching and experimental teaching styles. Co-TPACK consists of 3 cycles (Student Teachers' Preparation Cycle, Cooperating Science Teachers Cycle, and Collaboration Cycle (Co-teaching, Co-planning, and Co-Evaluating and Coaching System). Co-TPACK promoted an exchange of knowledge and experience related to science teaching among cooperating science teachers, student teachers, and university supervisors. Participants in the study used many channels for communication, including online forums.

[1] Corresponding Author: drsiriwankief@pkru.ac.th

Over time, they used more technology-integrated teaching and learning. Their continuous development is evident in their lesson plans and teaching practices.

KEYWORDS: Technological Pedagogical Content Knowledge (TPACK), Co-TPACK, Professional Development

INTRODUCTION

In Thai school-based environment, teachers play an important role in educational reform and science education (Chatmaneerungcharoen, et al, 2008; ONEC, 2001). Thai teachers are considered as important contextual factors and they are widely accepted as the heart of the learning reform. Because the Thai teachers are the most significant and indispensable component in the teaching and learning processes occurring in classrooms (Office of Rajabhat Institute Council, 2002). Especially, in the 21^{st} century, learning in the 21^{st} century context has dramatically changed (Beetham and Sharpe, 2013). The impacts of globalization and modern technology have brought changes upon Thai science education which requires science teachers to be knowledgeable and competent to prepare Thai students for an ICT society.

Technological Pedagogical Content Knowledge or TPACK framework (Koehler and Mishra, 2009) has emerged as a professional development framework to describe required science teachers' knowledge for the 21^{st} century science classroom. Emerging 21^{st} century era, science teachers should conceptualize TPACK that is referred to a specific category of knowledge for teaching science. TPACK is a conceptualized blend of technological knowledge, content knowledge and pedagogical knowledge to design Information and Communication Technological lessons in science concept. Teachers' knowledge influences what they know, what they think, and how they act in the classroom. TPACK was extended from Shulman (1986) who defines the knowledge of teaching a subject matter as pedagogical content knowledge (PCK): the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented, adapted to the diverse interests and abilities of learners, and presented for instruction. In the emerging 21^{st} century, people are taught to be familiar with technology because of global communication and information access. Given this change, education must shift to incorporate computer based, electronic technologies integrating learning with these technologies within the subject area. Now the knowledge benchmark that teachers need in order to teach their subject matter with technology is more than just PCK, it needs the development of "Technology Pedagogical Content Knowledge (TPACK)" (Mishra and Koehler, 2006; Niess, 2007). From the National Research Council (NRC) "The relationship between Science and Technology is so close that any presentation of science without developing an understanding of technology would portray and inaccurate picture of science" (NRC, 1996). Similarly, the International Society for Technology in Education developed new technology standards for students and teachers that specifically confront teachers with integrating technology throughout education. These standards direct that electronic technologies become " an integral component or tool for learning of academic subject area" (ISTE, 2000b). Therefore, the process of teacher education should focus to prepare the student teacher to have the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies. According to educational reform, teachers still have difficulties in implementing constructivist-based teaching and learning approaches. These approaches are seen to be radically new for the majority of science teachers and they are suspicious of their effectiveness (OEC, 2004). Particularly, there are numbers of studies that document the problems in-service elementary science teaching. Thai elementary school teachers often do not have enough pedagogical content knowledge necessary to create a constructivist classroom. Most importantly, they lack an understanding about how to represent science content in ways that are personally meaningful and potentially accessible to students (ONEC, 2001; Yutakom and Chaiso, 1999) of pre-service teacher education (Tanruther, 1994), as it provides student teachers with essential bridge between theory and practice and the opportunity to define and refine their teaching skills. Similarly, the current literature supports the importance of teacher practice, identifies student teaching as the most helpful part of professional education and comprises the first steps of a personal journey of becoming a teacher (Thibeault, 2004; Walkigton, 2005; Williams, 2001). In school-based pre-service teacher education, mentoring refers to the supervision of a student teacher by an experienced teacher during the teaching practice. Student Teachers are assigned to teacher (Cooperating teachers) to be supervised throughout the practicum. Additionally, students are supervised by a university supervisor who occasionally visits the school. The university supervisor and the cooperating teacher serve as mentors to the student teachers, as both of them interact with the protégé and help him or her learn again the necessary professional knowledge and skills (Healy and Welchert, 1990). Cooperating science teachers are selected with care and with the knowledge that their experience will provide a nurturing environment for the science teacher education student. It is of primary importance that the clinical experience be a positive experience for the student teacher. To capitalize on increasing access to technology, current teacher education has to focus on the importance of training both in-service and pre-service teachers to more effectively integrate technology into their teaching. Numerous studies have focused on development of teacher knowledge. Nevertheless, these studies do not indicate on how to support teachers 'development of TPACK continually with their school based context and the key elements of PD should be address. Therefore, this study is for preparing the cooperating science teachers with appropriate TPACK and supervisory skills. They will be ready for working with their student teachers in the 21st century.

This study examines the enhancement of Cooperating science teachers' technological pedagogical content knowledge [TPACK] through the Co-TPACK professional development program (Co-TPACK PD) in internship placement. The research objectives are expressed through the following research questions.

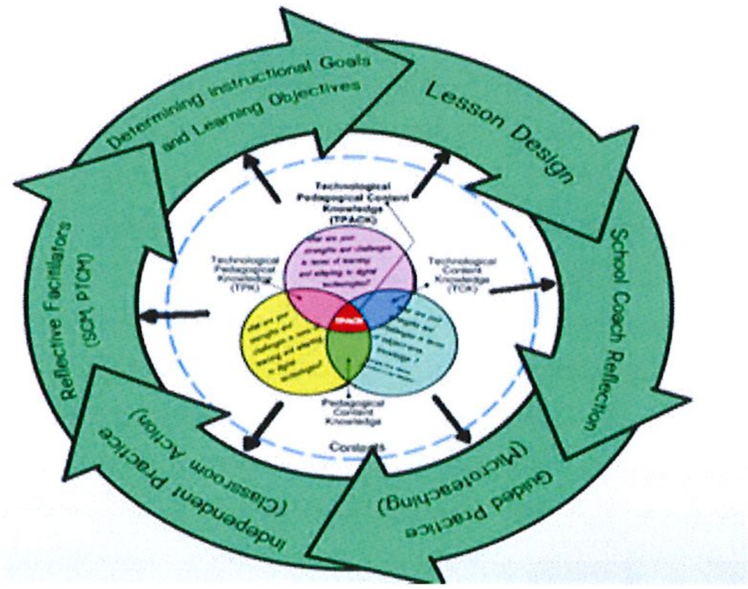
1. What are some of the characteristics of the science cooperating teachers' and students' TPACK developed during Co-TPACK PD?
2. What are characteristics of Co-TPACK PD?

RESEARCH OBJECTIVES

1. Examine the development of science cooperating teachers' and student teachers' TPACK during Co-TPACK PD.
2. Determine the characteristics of a Co-TPACK PD.

RESEARCH METHODOLOGY

This TPACK Study is based on the interpretive research framework and conducted using grounded theory as its research methodology. The primary goal of grounded theory is to generate theory inductively from data. The data analysis focused on assessing how science cooperating teachers develop their technological pedagogical content knowledge through Co-TPACK PD. This study was conducted for 2 years following the research framework which is presented in Picture 1.



Picture 1: Research Framework

The professional development program (PD) was initial designed with the following features: determining instructional goals and learning objectives; working on lesson design; participating in school coach reflection; starting with guided practice (microteaching); implementing into real classroom/ independent practice; and Observing by team member as reflective facilitator. Each of activities consisted of providing opportunities for teacher collaboration and teacher reflection on what they are learning and how they apply what they learned. The teachers' comments were used as valuable tools for teacher learning and teacher changing their TPACK.

RESEARCH PARTICIPANTS.

The research participants were 40 science cooperating teachers and 48 student teachers in major of General Science, Faculty of Education at Phuket Rajabhat University. This purposive sampling method is based on the criteria that the researcher would like to learn and find the answer for research questions. Forty science cooperating teachers indicated their willingness to participate in the study. In the end three criteria were used for choosing the participants and they were as follows:

1.1.1 Teachers who were teaching Science subject in the elementary and high school levels in schools located in the Phuket Province. They were cooperating teachers who worked with student teachers in 2017 academic year.

1.1.2 The teachers were teaching Science in both semesters and could participate in long term professional development program. They showed a willingness to contribute to the profession by being open to classroom observations by the researcher, participate in follow-up interviews and be able to attend meeting of the TPACK PD for 2 years

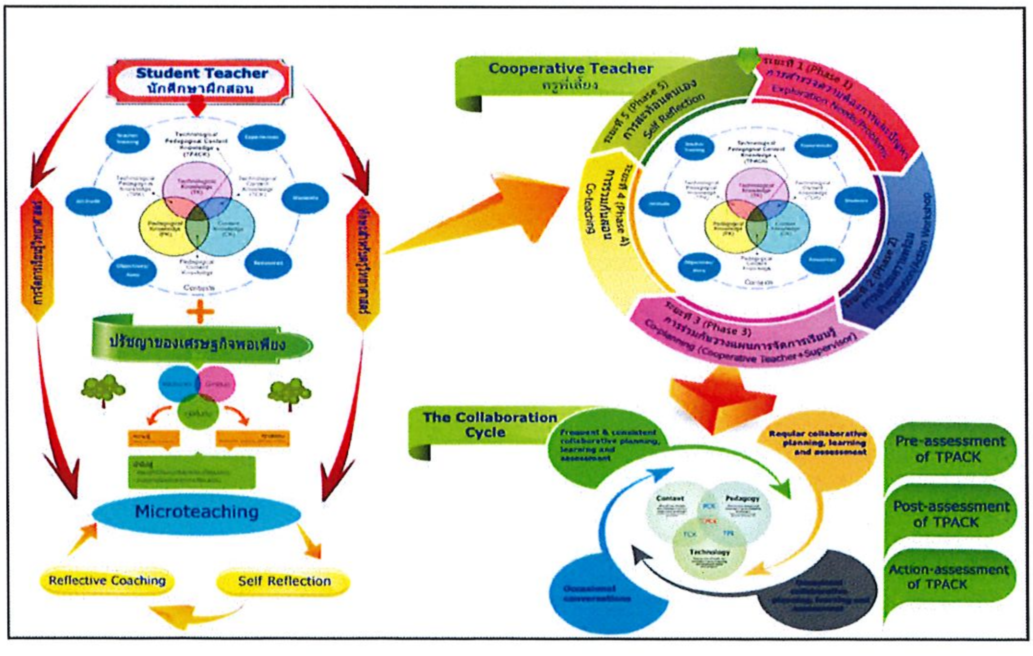
RESEARCH INSTRUMENTS

In order to study the development of Thai science cooperating teachers' understanding of TPACK and practice through CO-TPACK PD, multiple data sources have been used during the research process. In interpretive case study, classroom observation, individual interview, questionnaire, inquiry-based lesson plan, written reflection, and group discussion are preferred to assess all teachers' TPACK with their thinking, actions, and reasons in the specific context and setting. In this research, classroom observation, interview, TPACK- questionnaire, case study, card sort (interview by situation) and documents were used as research methods to provide opportunities for participants and the researcher to generate an understanding for a particular situation. Research participants present their TPACK through writing lesson plans, teaching journals, meeting, card sorting, and answering or discussing topics in the interview process. An understanding of their TPACK was transcribed and explained by the researcher who has used the inductive approach to generate theory.

The Co-TPACK PD PROGRAM and DATA COLLECTION

The study reported in this research is aimed at identifying how a Co-TPACK PD impacts on the development of cooperating science teachers' TPACK, and how does the Co-TPACK PD look like. There are three main criteria of trustworthiness: internal validity, reliability, and external validity. This study collected participants' background on their prior knowledge, skills, and competence regarding to teaching science. 2 years program with research and development was the strategies for enhancing credibility which is prolonged engagement by investing sufficient time to reach purposes, persistent observation by identifying issues or elements that are most relevant to the research, triangulation by using different sources, multiple methods of data collections, and multiple co-researchers, probing researcher s' bias, establishing the adequacy of critiques written for evaluation purposes, and participants' checking of data collection and data analysis. Moreover, the researcher provided a thick description to enhance transferability of research findings that enables other researchers to determine how closely their situations and contexts and whether research results can be transferred.

The three stages of Co- TPACK PD were provided guidelines for designing professional learning contexts for teacher development of TPACK knowledge and gave the detail how to collect data with the research instruments. This professional development program is shown as below (picture 2).



Picture 2: CO-TPACK PD

This diagram is explained with Co-TPACK I, Co-TPACK II, and Co-TPACK III as following.

Co-TPACK I: Integrating Technology in the Pre-service Science Teacher Preparation Program (Semester of 2016 Academic Year)

Forty eight pre-service science teachers were attending Science Education course integrating ICT for one semester induration and emphasized learning through hands-on design of ICT lesson plans. The course was aimed at preparing pre-service science teachers to design student-cantered ICT-integrating science lessons that support the 21st century in Thai students. The pre-service science teachers' course was conducted 4 months (3 hours/lesson). The first two months were interactive lectures and workshops on Thai National Science Curriculum, science teaching methods, measurement and evaluation in science classroom. The last two months were about technological training, ICT lesson design in concepts of science, and microteaching lesson study. The specific technology section used science problem-based activities to guild the pre-service science teachers in learning about educational technologies, pedagogical considerations with these technologies and teaching/learning with these technologies. The first stage of the program, the student teachers explored a variety of science concepts integrating technologies that could be considered in the curriculum. Microteaching lesson study section focused the pre-service science teachers gaining teaching experience, reflective skill on lesson plan development fours instructional methods: demonstrations, hands on/ laboratories, inductive and deductive activities. The pre-service science teachers were assigned to develop a science lesson for each model that has to integrate with technology. The pre-service science teachers teach (videotaping the instruction and upload on Facebook group by YouTube link) their lessons to their peers, and reflect (assessing and revision though written reflective journal and group discussion). The microteaching lesson study is recorded by videotapes to recall the teaching and debriefs of the lessons by their peer, instructor and ICT experts. The remaining 6 months of the program focused specifically on providing extended ICT workshops and professional classroom observations. Prior to the student teachers starting their fulltime practicum at the school sites, the student teachers were assigned to work with their cooperating teachers to design their sequence of lessons for an integration of technology.

Co-TPACK II: Pre-service science teachers' Practicum (Semester of 2017 Academic Year)

During fulltime student teaching, the pre-service science teachers were expected to adjust their lesson plans under the supervision of supervisor (researcher) and cooperating teachers. The technology integration theme highlighted in the shaded areas provided the explicit preparation of the pre-service science teachers' development of knowledge needed for development of TPACK. During teaching practicum, the pre-service science teachers were observed by their cooperating teachers and supervisor, all assignments were collected and analyzed, and the case studies were interviewed extensively over the various parts of the program. After each lesson, the pre-service teachers prepared written reflections that considered revised plans for succeeding lessons. They were assigned to reflect on their understanding of science concepts, instructional methods, learning and teaching assessment, the success of the integration of technology in the lesson and recommendations for the changes, and their teaching while integrating technology in teaching science. With Co-TPACK II, the cooperating teachers were provided the opportunities to observe and exchange their ideas with university supervisor and experts regarding their pre-service students' practicums.

Co-TPACK III: Cooperating science teachers' development of TPACK (Semester of 2017 Academic Year)

The main goal of this stage is promoting the cooperating science teachers' awareness of the significance of integrating technology into their practices. The researcher explained the purpose of the activity. After the teachers share their ideas on what they believe with integrating technology instruction on students' learning? The teachers were assigned to analyze and share their thoughts with TPACK members. In sharing and discussing this activity, the researcher used questions for guiding the teachers to create the essential features of technology based teaching in aspect of goals or purposes for teaching science, students and teacher role in active -based classroom, and some important features of inquiry process such as students' interest and curiosity is an important aspect that teacher should use for starting the classroom. Moreover, the implicit purpose of this activity was to prepare the teachers for the further activity of Co-TPACK PD in which they were asked to share and create technology based lesson plans with their pre-service teachers.

During collaborating among cooperating teachers, student teachers, and researcher (university supervisor), data collection was gathered. The researcher showed cooperating teachers' VDO teaching and their technology-based lesson plans via visualizer and LCD projector. These lesson plans were selected by the teachers independently. After the presentation of each teacher's teaching, the teachers had chance to discuss and critique on their teaching and their lesson plans. The teachers reflected their teaching and lesson plans, provided suggestions, and support Co-TPACK team member success. The topics that were used in the discussion included: classroom context, goals or purposes for teaching science, science content, teaching strategy, learner and learning, science curriculum, science learning assessment, and technology integration. In addition, this discussion also focused on the teacher role, the student role, and issues of concern. After discussion of all teachers' teaching and lesson plans, the researcher asked the teachers to compare and contrast their lesson plans in order to seek out the essence of inquiry teaching and share their TPACK.

DATA ANALYSIS

The researcher analyzed documents and underlying knowledge of participants in speaking and writing. Data from multiple sources such as teachers' journals and interviews; field notes and videotapes from observations and card sorting were analyzed by the process of open coding to get the transcripts from the first interview, observation, reflection and card sorting. In developing categories, the researcher used a constant comparative method of analyzing multiple sources of data served to triangulate the data in order to increase trustworthiness of the research findings and assertions made. In the data analysis methods, the researcher attempted to find out patterns of growth or development by comparing the science cooperating teachers' understanding of TPACK and practices through CO-TPACK PD, in both initial and final stages of the model using multiple sources of data. The approach to analysis involved an inductive process: categorical aggregation and a search for correspondence and patterns. Because this study employed a multiple case research design, the data analysis methods began with within-case analysis and followed by cross-case analysis. Triangulation was used to describe the idea that the researcher tried to construct an explanation by using more than one.

RESEARCH FINDING

As the CO-TPACK PD progressed during internship placement, cooperating science teachers' TPACK knowledge base gradually broadened through learning activities in the CO-TPACK PD. Majority of cooperating science teachers have grown in their TPACK. Cooperating teachers were provided with many opportunities to broaden their understandings and practices about science concepts, pedagogy, assessment, technology integrated teaching and the nature of science. They had a chance to express their initial understandings and compare these understandings to constructivist understandings of teaching and learning science, proposed in the Basic Education Curriculum, and the Science Curriculum Framework. The Cooperating teachers were provided interesting ideas from the CO-TPACK members through sharing, reflecting, and discussion during their co-planning, co-teaching, and co-evaluating. Through these activities, cooperating teachers' understanding and practices of TPACK supporting teaching and learning science based on constructivism shifted to more constructivist understandings specifically, in the nature of scientific knowledge including the teacher 's supervising skill which was increased

The participants gained technological content knowledge in the use of both Weblogs and Facebook for sharing knowledge and experiences for example:

> Weblog writer (pre- service teacher): *Before any investigation about transmission of light, it is essential that all students clearly understand what is meant by transparentม , translucent, and opaque. With making students understand this concept equally, teacher can move on with comfort of knowing that all students are starting their exploration on equal prior knowledge.*
>
> Cooperating teacher: *Yes, it is very important. Teacher must clarify terminology used by students to ensure they have correct understanding. I always used post-it paper with my students and asked them to write their answers about "Do I know anything about this topic? And What do I know?"*

Cooperating and Pre-service Teachers Conversation through weblog.

The case studies are more confident of their TPACK perceptions. The finding presents that the pre-service science teachers and cooperating teachers tend to give more considerations to integrate technology into their lessons in three aspects (resource, teaching material, and student assignment). Through CO-TPACK PD and guided supervision within the school site enhances the student teacher's development of TPACK based on educational theories and knowledge. This includes providing an effective way to convey the use of the technology to enhance student learning such as YouTube, Anusura, Dreamweaver, and Flash for publishing student work online. By experiencing these different multimedia applications, they realized that they could represent many concepts to their students through technology. In an opposite way, students can learn science by creating project-based learning. For example,

> *I would like to suggest another tool for presenting student's work. I love this website. It calls ePubBud. Like any other website that provides a service, the first thing students must do is sign up with an email address. After that, you are free to start working on your eBook! Like Flipsnack, ePubBud which allows students to upload images that get created into an eBook, or students are free to create*

the eBook through ePubBud's interface. Once the students finish creating their books, save it and send their book's link to teachers, parents, or friends.

Cooperating

Teachers A

Sharing, reflecting, and discussing during co-planning, co-teaching, and co-evaluating of CO-TPACK PD were key activities in the CO-TPACK PD that enhanced Cooperating teachers' TPACK development. Through participating in the CO-TPACK PD, cooperating teachers' understanding about student-centered learning became clear. In their broadened ideas, student prior knowledge, and participating in hands-on activities were key aspects of student-centered teaching. Cooperating teachers also had a chance to clarify their understanding of how to integrate knowledge bases for teaching particular content with technology with their student teachers and university supervisor. Practicum reflection was used to help the cooperating teachers become aware of the importance of each knowledge base for teaching and its integration. In their second lesson plan, learning goals and purposes, learning activities sequence, instruction media, and assessment methods, had more detail and were more interrelated. They appeared focused more on teaching science by inquiry approach and enhanced students to learn science by integrated learning, PBL, or experimental learning as dimensions of student learning. They changed to use a variety of assessment methods such as asking questions of students, observing their behavior, creating mind mapping and interaction with them. Technology based teaching was used in steps of challenging students with real situations through VDOs (news, TED talks) and students 'present their works. These student-student and student-teacher interactions appeared in their microteaching activity and their supervising to their student teachers. The Cooperating teachers showed the CO-TPACK team can help their TPACK development and supervising skill because the CO-TPACK PD (during internship placement) contained a friendly and comfortable environment, interesting teaching and learning activities, and various types of assessment methods. The results of study suggest several aspects need to be addressed for science teacher education (pre-service and in-service science education) to be successful in integrating TPACK in their teaching of science, particularly in a classroom similar to the case study teachers'. First, the science teacher needs to hold the goals and purposes that focus on student learning with respect to science knowledge, science process skills, and scientific attitude. When the cooperating science teachers can teach science along with the reform-based science teaching, the student teachers will be trained to teach science as the same way of their cooperating science teachers. Second, strong pedagogical knowledge would make it easier for the science teacher to teach science through inquiry-based teaching and learning.

RESEARCH DISCUSSION

The professional development program utilized in this study involved the use of basic elements of co-planning, co-teaching, and co-evaluating to promote the teachers' understandings and practices of TPACK for a reformed science classroom. They can implement their knowledge as theory into their actual practice in real classrooms. According to the results of this study, the CO-TPACK PD is productive in affecting changes of the case study teachers' understandings and practice of TPACK in the classroom. The crucial components underlining the CO-TPACK PD that are likely to have an impact on the development of the science teachers might be: establishing common goals among program members, empowering teachers' leadership of the professional development program, providing opportunities for teachers to learn in their actual classrooms, giving time and support for teachers to plan, implement, observe, and reflect on their lessons, providing chances for teachers to learn through other teachers who are colleagues, having long-term assistance for continuous learning and practical change, and most importantly building and sustaining a trusting and respectful atmosphere among the teachers and the researcher. In summary the results from this research has discovered an important way for the creation of professional teacher development in science. Professional development should be created by teachers' needs and their problems regarding teaching science in real situations. The professional development program should help science teachers in integrating all elements of knowledge; how to integrate content knowledge, teaching knowledge, including setting goals for teaching science, methods of teaching science, learners and learning, curriculum and assessment and evaluation. The development of targeted science teacher's knowledge should look to develop long-term collaborative working. The collaborative works in all three stages of the Co-TPACK model are effective opportunities for exchanging teachers' understanding of each aspect in TPACK. The teachers can then apply their understanding into practices properly. Opinions and experiences of individual teachers must be relevant to the needs of the teacher professional development program. The teachers said the most effective stages that helped them change their understanding and practice of TPACK were the co-planning and co-evaluating stages.

SUGGESTIONS

1. SUGGESTIONS FOR THE APPLICATION OF RESEARCH RESULTS

According to the results of this study, the Co-TPACK PD is productive in affecting changes of the teachers' TPACK in the classroom. The crucial components underlining the Co-TPACK PD that are likely to have an impact on the development of the science teachers might be: establishing common goals among program members, empowering teachers' leadership of the professional development program, providing opportunities for teachers to learn in their actual classrooms, giving time and support for teachers to plan, implement, observe, and reflect on their lessons, providing chances for teachers to learn through other teachers who are colleagues, having long-term assistance for continuous learning and practical change, and most importantly building and sustaining a trusting and respectful atmosphere among the teachers and the researcher. In summary the results from this research has discovered an important way for the creation of professional teacher development in science.

2. SUGGESTIONS FOR FUTURE RESEARCH

The results of this study indicate that participation in Co-TPACK PD was a successful strategy for promoting changes in science teachers' TPACK. However, the study did not continually investigate in aspect of improvement on student teachers' knowledge and their practices deeply. Therefore, future research should present how the student teachers develop their knowledge during Co-TPACK PD. For readers and researchers who are interested in doing similar studies, it is important to remember that this study was conducted with a group of science teachers. The findings from this study were not intended to generalize to all science teachers. Nevertheless, the description of how the Co-TPACK PD approach to professional development was implemented and the context surrounding the use of this approach may be useful to others who decide to use this as model for teacher professional development in their own context.

ACKNOWLEDGEMENT

My success would not be happened if I did not have help from the National Research Council of Thailand and Phuket Rajabhat University for providing me the scholarship. Furthermore, this research would not have been completed without the support from the group of experts, research participants, and school administrators. I would like to thank all of the English editors and especially my husband, Robert Kief, for his patience and devotion in proof reading my writing.

REFERENCES

Beetham, H., and Sharpe, R. (2013). **Rethinking Pedagogy for a Digital Age: Designing for 21st Century Learning**. New York: Routledge.

Charmaz, K. (2003). **Grounded theory. In: J. A. Smith Qualitative Psychology: A Practical Guide to Research Methods**. London: Sage.

Chatmaneerungcharoen, S. et al. (2008). The Elementary Science Teachers' Pedagogical Content Knowledge and Practices of Schools under the Bangkok Metropolitan Administration. **KKU Research Journal, 14**(12), 1132-1142.

Healy, C. C., & Welchert, A. J. (1990). Mentoring relations: A definition to advance research and practice. **Educational Researcher, 19**(9), 17–21.

International Society for Technology in Education. (2000a). **National Educational Technology Standards for Teachers. International Society for Technology in Education (ISTE).** Retrieved January 24, 2017, from http://www.iste.org

International Society for Technology in Education. (2000b). **National Educational Technology Standards for Students: Connecting Curriculum and Technology.** Eugene, OR: Author.

Koehler, M., and Mishra, P. (2006). Technological Pedagogical Content Knowledge: A new framework for teacher knowledge. **Teachers College Record, 108**(6), 1017-1054.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. **Contemporary Issues in Technology and Teacher Education, 9**(1), 60-70.

National Research Council. (1996). **The National Science Education Standards.** Washington, DC: Brooking Institution.

Niess, M. L. (2007). **Mathematics Teachers Developing Technological Pedagogical Content Knowledge (TPCK).** Paper presented at IMICT 2007, Boston, MA.

Office of the Education Council (OEC). (2004). **Education in Thailand 2004.** Bangkok: Amarin Printing.

Office of the National Education Commission (ONEC). (2001). **The Research Report for Comparing of Educational Reform to Know in Thai Science Education Reform.** Bangkok: ONEC.

Office of the Rajabhat Institutes Council. (2002). **Quarterly Report on World Bank project -The Secondary Education Quality Improvement Project.** IBRD Loan 4052 TH. Bangkok: Author.

Shulman, L. (1986). Those who understand: Knowledge Growth in Teaching. **Educational Researcher, 15**(2), 4–14.

Tanruther, E. M. (1994). What does it mean to be a supervisory teacher? **College Journal, 1**, 167-171.

Thibeault, J. (2004). **The Relationship Between Student Teachers and Cooperating Teachers as a Foundation for the Development of Reflective Thinking: An Exploratory Study Based on Student Teachers' Perceptions.** Unpublished doctoral dissertation. McGill University, Montreal, Canada.

Yutakom, N., & Chero, P. (1999). **Reporting of In-service Science Teacher Professional Development in Accordance with the National Education Act of B.E. 2542.** Bangkok: IPST.

Walkington, J. (2005). Becoming a teacher: encouraging development of teacher identity through reflective practice. **Asia-Pacific Journal of Teacher Education, 33**(1), 53-64.

Williams, C. C. (2001). **Student Teacher Perceptions of University Supervisor Performance.** Unpublished dissertation, Tennessee State University.