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DEVELOPING PRE-SERVICE TEACHERS' TECHNOLOGY INTEGRATION EXPERTISE THROUGH THE TPACK-DEVELOPING INSTRUCTIONAL MODEL

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ABSTRACT

This study describes the TPACK-Developing Instructional Model which prescribes an instructional process for developing pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) during the instruction of Information and Communication Technology (ICT) tools. This model proposes three phases for developing teachers' TPACK through ICT instruction. The phases are: fostering teachers' acceptance and technical proficiency; pedagogical modeling; and pedagogical application. An ICT instructional intervention designed with this model as its framework and its effects on the TPACK development of 74 pre-service teachers were examined. Qualitative analyses of their course reflection comments found that they predominantly developed Technological Knowledge and Technological Pedagogical Knowledge. More emphasis on subject-focused pedagogical modeling, product critique, and peer sharing may better develop their Technological Content Knowledge and TPACK. Future developments of the TPACK-Developing Instructional model are discussed.

According to Shulman (1986), teachers' understanding of the teaching practice is formulated from the integration of their content knowledge with their pedagogical

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knowledge. Shulman termed this unique form of knowledge as pedagogical content knowledge and proposed that it can be used to represent teachers' professional expertise. Mishra and Koehler (2006) added technological knowledge to Shulman's conception and proposed that technological pedagogical content knowledge can be used to represent teachers' technology integration expertise. Thompson and Mishra (2007) also gave technological pedagogical content knowledge the acronym of TPACK to emphasize teachers making connections between their Technological, Pedagogical, *and* Content Knowledge when integrating technology. This conception of TPACK addressed a theoretical void in the field of Information and Communication Technology (ICT) in education because it articulated the different types of knowledge needed by teachers for technology integration (Mishra & Koehler, 2006). It therefore posed a challenge to teacher educators to examine how ICT courses can be better designed to foster TPACK (see examples in The AACTE Committee on Innovation, 2008).

Teachers' TPACK development during ICT instruction has most often been studied with respect to their engagement in design projects (Angeli & Valanides, 2009; Koehler & Mishra, 2005a, 2005b). Other instructional strategies such as faculty modeling and computer skills instruction have been successfully used to foster teachers' attitudes and abilities for technology integration (Strudler & Wetzel, 1999). However, their impact on teachers' TPACK development has yet to be thoroughly examined, which is a gap in TPACK research. It is also important to analyze these instructional strategies because Niess (2005) found that teachers' TPACK development process was multi-faceted—it involved them making attitudinal change, acquiring technological skills, and creating pedagogical ideas for technology integration. Design projects may need to be used in conjunction with other instructional strategies to foster teachers' TPACK development. However, such an instructional model has yet to be developed.

Therefore, this study proposes the TPACK-Developing Instructional Model which supports the TPACK development process as described by Niess, Suharwoto, Lee, and Sadri (2006) and Niess (2007). It prescribes three instructional phases for developing teachers' TPACK as they learn to use new and unfamiliar ICT tools. The first instructional phase aims to foster teachers' acceptance of a new ICT tool through faculty modeling while the second and third phases build their technical proficiency and technology integration expertise through computer skills instruction and design projects respectively. Each instructional phase supports teachers to develop TPACK through activities that strengthen the connections among their technological knowledge, pedagogical knowledge, and content knowledge. The article first articulates the theoretical rationale for this model by drawing on existing literature in the area of TPACK, teacher education, and ICT instruction. It then examines how an ICT course designed with the TPACK-Developing Instructional Model impacts the TPACK development of 74 pre-service teachers. The contributions of this model to TPACK-developing ICT instruction are then discussed.

THEORETICAL DEVELOPMENT

TPACK Constructs

Mishra and Koehler (2006) conceptualized TPACK as a seven-construct framework as shown in Figure 1.

It comprises three main knowledge sources:

1. Technological Knowledge (TK) – knowledge of technology tools.
2. Pedagogical Knowledge (PK) – knowledge of teaching methods.
3. Content Knowledge (CK) – knowledge of subject matter.

It also comprises of four other types of technology integration knowledge that are derived through the connections among technological knowledge, pedagogical knowledge, and content knowledge. These are:

4. Technological Content Knowledge (TCK)—knowledge of subject matter representation with technology.
5. Technological Pedagogical Knowledge (TPK)—knowledge of using technology to implement different teaching methods.
6. Pedagogical Content Knowledge (PCK)—knowledge of teaching methods with respect to subject matter content.

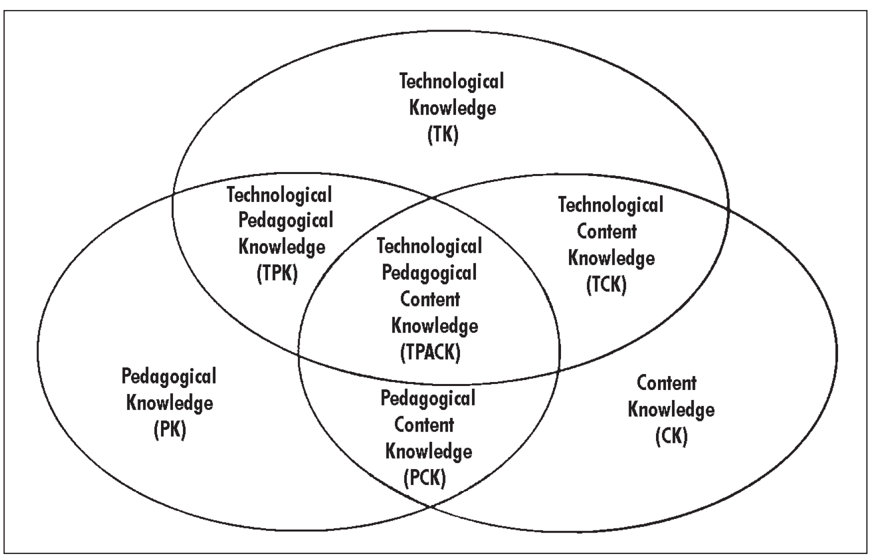

Figure 1. TPACK framework, as depicted by Mishra and Koehler (2006).

7. Technological Pedagogical Content Knowledge (TPACK)—knowledge of using technology to implement teaching methods for different types of subject matter content.

These seven constructs characterize the different types of knowledge teachers need for technology integration.

TPACK Development during ICT Instruction

Koehler and Mishra (2005b) proposed TPACK to be an emergent form of knowledge that is best developed when designing solutions for authentic technology integration problems. Teacher educators have shown considerable interest in exploring how design projects can be used to foster teachers' TPACK during ICT instruction. Koehler, Mishra, and Yahya (2007) used the seven TPACK constructs to code the classroom discussions of 18 graduate students across a semester-long ICT design project. Technological knowledge, pedagogical knowledge, and content knowledge were found to occur more frequently in students' discussions at the beginning of the semester. However, the frequencies of technological pedagogical knowledge, technological content knowledge, and TPACK became larger at the end of the semester. Other studies of ICT design projects also found it to be favorable for fostering teachers' TPACK development (Angeli & Valanides, 2009; Koehler & Mishra, 2005a).

These findings, though favorable, do not provide a complete picture of how teachers' TPACK development can be fostered through ICT instruction. Prior to the conceptualization of TPACK, many teacher education institutions have already experienced much success with their ICT programs. Those with exemplary ICT programs have used strategies such as faculty modeling, computer skills instruction, and design projects to foster positive attitudes toward technology integration among teachers, enhance their ICT proficiency, and provide hands-on experience for designing technology-integrated lessons respectively (Strudler & Wetzel, 1999). The current emphasis on design projects has led to a dearth of studies on how these other proven ICT instructional strategies may impact teachers' TPACK development. Yet, the complex nature of teachers' TPACK development process may suggest the need to look beyond just using design projects for ICT instruction.

Niess et al. (2006) and Niess (2007) studied the TPACK development of different cohorts of teachers as they attended a development program on the use of spreadsheets for Mathematics. Their qualitative analysis of classroom observation and interview data found teachers demonstrating five stages of TPACK development that are described as follows:

1. Recognizing the utility of spreadsheets.
2. Accepting that spreadsheets can be used pedagogically.

3. Adapting lesson ideas they have explored in implementing spreadsheets for teaching.
4. Exploring new ways of teaching content with spreadsheets.
5. Advancing the uses of spreadsheets beyond content teaching.

Different ICT instructional methods are needed to support each stage of teachers' TPACK development. In the early stages of teachers' TPACK development, instructional methods that foster their attitudinal change and improve their technical proficiency with an ICT tool could be more pertinent. This is especially so when teachers are encountering new and unfamiliar ICT tools. On the other hand, the modeling of technology integration paradigms may be more important for supporting their TPACK development at Stage 3 and beyond. Instructional strategies such as faculty modeling and computer skills instruction that have previously been used successfully in exemplary ICT programs need to be revisited. The integration of these strategies into a systematic process for TPACK-developing ICT instruction is necessary.

The TPACK-Developing Instructional Model

This article, therefore, proposes a TPACK-Developing Instructional Model that takes into account the stages of teachers' TPACK development. The five stages described by Niess (2007) were used to guide the development of the following three instructional phases (see Figure 2).

Phase 1 – Foster Acceptance

Niess (2007) reported that when confronted with a new ICT tool, teachers began their TPACK development by first recognizing and accepting its pedagogical utility. Therefore, the first phase of the TPACK-Developing Instructional Model recommends that the instruction of new ICT tools to teachers should begin with instructional strategies that help them to foster acceptance for using the tool pedagogically. According to Bandura (1977), vicarious experiences obtained through the observation of successful task performance by others can enhance one's confidence for performing the same tasks. When teacher educators use an ICT tool to support their own instruction, teachers have opportunities to observe how it is being integrated. This is a form of vicarious experience which can foster their acceptance of the tool. Studies of pre-service teachers have found that such kinds of modeling by their teacher education faculty helped them to become more confident about using ICT tools for instructional purposes (Beyerbach, Walsh, & Vannatta, 2001; Brush, Glazewski, Rutowski, Berg, Stromfors, & Hernandez Van-Nest, 2003; Pope, Hare, & Howard, 2005; Strudler & Wetzel, 1999). Therefore, Phase 1 of the TPACK-Developing Instructional Model recommends that faculty modeling should be used to foster pre-service teachers'

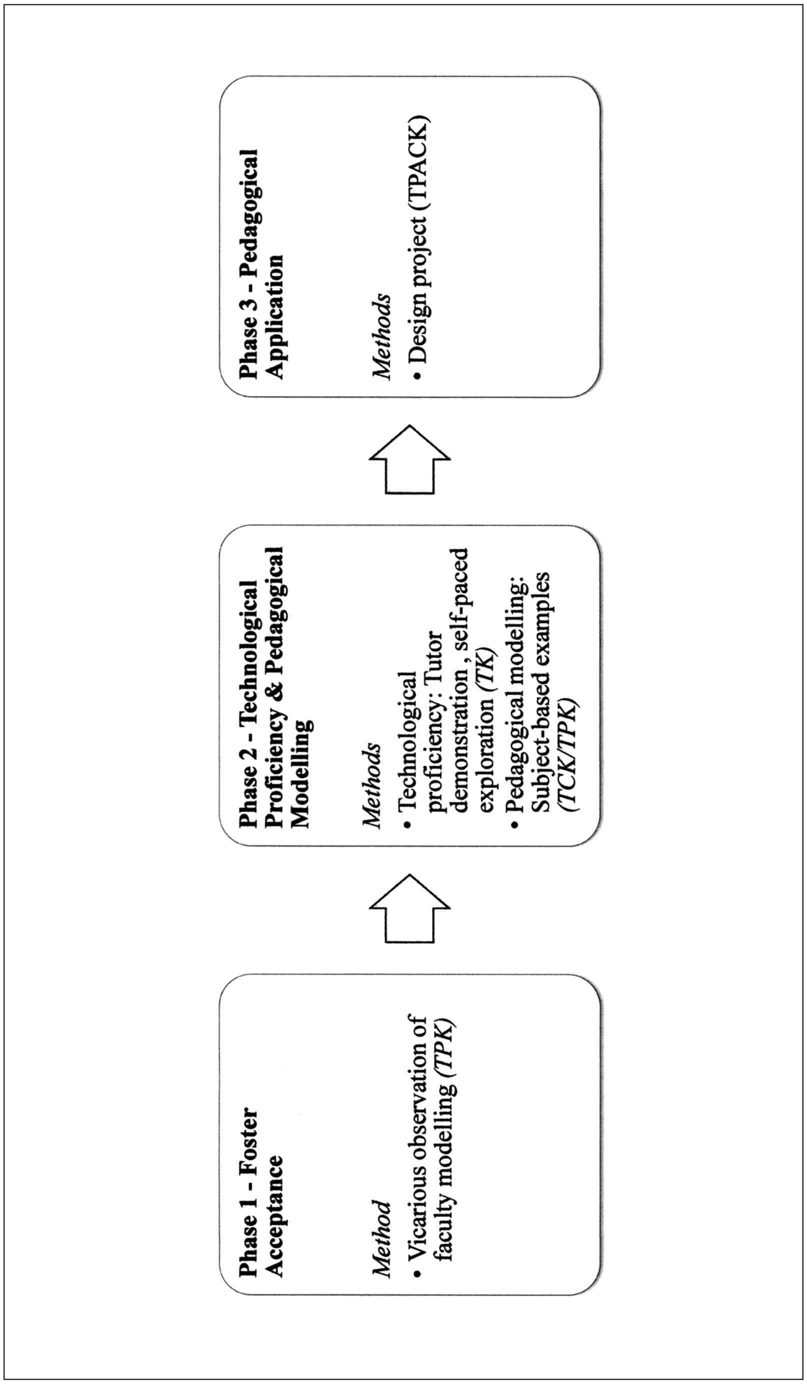

Figure 2. The TPACK-Developing Instructional Model.

acceptance of an ICT tool. This process is especially important if an ICT tool is new and unfamiliar to pre-service teachers.

During student teaching, pre-service teachers were found to use ICT tools in similar ways as those modeled by their faculty during class (Brush et al., 2003; Doering, Hughes, & Huffman, 2003). These teachers could have learned the pedagogical uses of ICT tools through their vicarious experiences of faculty modeling. No previous study has analyzed the effects of faculty modeling with respect to the seven TPACK constructs. Therefore, from the discussions, it is postulated that teachers would develop some form of technological pedagogical knowledge through faculty modeling during Phase 1.

Phase 2 – Technological Proficiency and Pedagogical Modeling

Niess (2007) found that once teachers have accepted an ICT tool, they will begin to make appropriate pedagogical use adapting from lesson examples available to them. The TPACK-Developing Instruction Model proposes that teachers' technological proficiency for an ICT tool needs to first be developed before various lesson examples are provided to them for exploration. This is because even experienced teachers were unable to foster student-centered learning with an ICT tool when they lacked adequate technological proficiency with it (Pierson, 2001).

In recent years, schools of education have given more emphasis to technology integration instruction rather than computer skills instruction. Therefore, recent literature exploring the methods of teacher computer skills instruction has been relatively sparse. Earlier studies, such as Albion (2001), found that tutor demonstrations of ICT tools are an effective method for computer skills instruction. However, a more recent study by Koh and Frick (2009) found that pre-service teachers were more motivated in their computer skills learning when a combination of tutor demonstration and student self-paced exploration was used. Therefore, the model proposes that both these methods for computer skills instruction be used during Phase 2 to enhance teachers' tool-specific technological knowledge.

Teachers' acquisition of tool-specific technological knowledge lays the foundation for them to consider its pedagogical uses. Phase 2 of the TPACK-Developing Instructional Model suggests the use of pedagogical modeling, which is most often exemplified in the incorporation of subject-specific technology tools into ICT courses or methods courses (Brush et al., 2003; Pope et al., 2005). Pedagogical modeling is first used to show how the technological affordances of an ICT tool can be used to the support the different methods of teaching. This is expected to help teachers foster some level of technological pedagogical knowledge. Second, pedagogical modeling should be specific to the subject that the teachers are teaching so that they can appreciate how the affordances of the ICT tool can be manipulated to represent their teaching content more effectively. The expected benefits of such content-based modeling are to assist teachers' to make the relevant connections between their technological knowledge and content knowledge, thereby formulating technological content knowledge.

Phase 3 – Pedagogical Application

Figure 1 shows that TPACK can be understood as the intersection between technological pedagogical knowledge, technological content knowledge, and pedagogical content knowledge. Phase 3 of the TPACK-Developing Instructional Model provides teachers with opportunities to make these connections, thereby formulating TPACK. TPACK is more contextualized to specific lesson topics and activities as compared to the other types of knowledge in the TPACK framework (Cox & Graham, 2009). To formulate TPACK, it is recommended that teachers undertake projects where they design ICT-integrated lesson for a selected lesson topic.

The use of design projects as an instructional strategy is not new in ICT curriculum. Many schools of education have reported that hands-on design projects were effective for helping pre-service teachers to foster technology integration know-how (Pope et al., 2005; Strudler & Wetzel, 1999), which concur with TPACK studies. As described in the earlier section, there is strong evidence that design projects help teachers to develop TPACK (Angeli & Valanides, 2009; Koehler & Mishra, 2005a; Koehler et al., 2007). This is envisioned to help teachers advance to Stages 4 and 5 of Niess' (2007) TPACK development process whereby they are able to explore and advance the pedagogical uses of an ICT tool.

AN EXAMPLE OF ICT INSTRUCTION USING THE TPACK-DEVELOPING INSTRUCTIONAL MODEL

The process outlined by the TPACK-Developing Instructional Model is exemplified through a 7-week program designed by a higher education institute in Singapore to teach the pedagogical uses of the Interactive Whiteboard during the July semester of 2009. A literature search of teachers' Interactive Whiteboard learning behaviors showed that teachers needed technical skills training on Interactive Whiteboard features (Hodge & Anderson, 2007) and pedagogical modeling (Miller & Glover, 2007) before they could fully exploit the affordances of the Interactive Whiteboard. According to tutors' feedback about the ICT experiences of the pre-service teachers they have taught in past semesters, most of them have not used the Interactive Whiteboard prior to the program. Therefore, The TPACK-Developing Instructional Model was used to conceive this instructional segment for the Interactive Whiteboard because it was designed to support teachers' attitudinal, technical, and pedagogical development as they learned the pedagogical uses of ICT tools that were new and unfamiliar to them. This 7-week segment was conducted as part of a 12-week core ICT module that the pre-service teachers were attending.

The process of this intervention is outlined in Table 1. Even though the actual instruction of the Interactive Whiteboard did not begin until Week 8 of the semester, Phase 1 of the TPACK-Developing Instructional Model was activated during Weeks 4 through 7 of the semester through faculty modeling. Phases 2 and 3 were implemented between Weeks 8 to 10.

Pre-service teachers were also attending methods courses related to their teaching subjects concurrently with this ICT module. Therefore, content knowledge and pedagogical content knowledge were not specifically addressed in this ICT module, but were covered in their methods courses.

OBJECTIVES OF STUDY

This study examined the development in pre-service teachers' TPACK as a result of an instructional intervention designed with the TPACK-Developing Instructional Model. The following research question was studied:

> How did pre-service teachers' TPACK for using the Interactive Whiteboard develop throughout the three phases of the TPACK-Developing Instructional Model?

It was hypothesized that during Phase 1, pre-service teachers would predominantly be developing technological pedagogical knowledge through observing faculty modeling of the tool. During Phase 2, tutor demonstrations and pre-service teachers' hands-on exploration would facilitate the development of their technological knowledge while the resource examples were expected to facilitate the development of both their technological pedagogical knowledge and technological content knowledge. In Phase 3, the pre-service teachers involvement in design projects would predominantly facilitate TPACK development.

METHODOLOGY

Study Participants

The participants involved in the study were 74 pre-service teachers from the three classes selected to pilot-test this Interactive Whiteboard instructional intervention. They were being prepared to teach in primary schools and were attending their first semester of teacher education training. About 85% of them were females and 60% of them were below the age of 25. An informal check by the first author, who was also the tutor, found that they lacked prior experience with using the Interactive Whiteboard. This concurred with the pre-study survey which found that 90% of the respondents (n = 48) had no prior experience with using the Interactive Whiteboard. Their lack of prior experience with the Interactive Whiteboard also meant that it was a new and unfamiliar ICT tool.

Table 1. The TPACK-Developing Instructional Process for Interactive Whiteboard Instruction

Stages	Week of semester	Interactive Whiteboard Lesson activities	Study data collection
Pre-study	1-3	Nil	Week 3: Pre-study survey
Phase 1 – Foster acceptance	4-7	*Faculty modeling:* Tutor facilitated weekly lesson presentations using the Interactive Whiteboard.	Week 7: ***Phase 1*** TPACK Reflection
Phase 2 – Techno-logical and pedagogical modeling	8 (Interactive Whiteboard instructions begin)	*Technological proficiency:* Tutor demonstrated basic Interactive Whiteboard features, e.g., pen, eraser, highlighter, magnifier, and spotlight. Pre-service teachers explored the functions of the Interactive Whiteboard board and Notebook software (the software that complements the Interactive Whiteboard) independently supported with screen cast videos and an online tutorial. The computer-lab was also made available for them to explore the Interactive Whiteboard software and board throughout the week. *Pedagogical modeling:* Pre-service teachers reviewed a database of subject-specific Interactive Whiteboard activities that were created by teachers in the United States, Australia, and the United Kingdom through self-exploration.	Week 8: ***Phase 2*** TPACK Reflection
Phase 3 – Pedagogical application	9-10	*Project Design:* Pre-service teachers worked in groups of 3-4 to produce three examples of Interactive Whiteboard lesson activities that were shared with the class during Week 10.	Week 10: ***Phase 3*** TPACK Reflection Week 12: Post-study survey

Data Collection and Analysis

A design-based approach (Lesh, Kelly, & Yoon, 2008) was adopted and this was the first of a series of iterative development-testing-revision cycles to improve the TPACK-Developing Instructional Model. The research question was answered through qualitative analysis of pre-service teachers' end-of-class reflections. This method of data collection was used because prior studies of teachers' pedagogical content knowledge have found it difficult to elicit their intended instructional practices without engaging them in reflection about it (Baxter & Lederman, 1999). Similar analyses of data collection methodologies for technological pedagogical content knowledge have not been conducted. Therefore, this study referred to proven methodologies used in pedagogical content studies and collected student reflections during Weeks 7, 8, and 10 which corresponded to the completion of Phases 1, 2, and 3 prescribed by the TPACK-Developing Instructional Model. Pre-service teachers worked in groups of three or four to discuss and post their reflection to two questions listed in the class discussion forum during the last 20 minutes of class during Weeks 7, 8, and 10:

1. How do you think you can use the Interactive Whiteboard tool/software in your classroom?
2. How did you and your team members learn about the Interactive Whiteboard tool/software? Describe your individual experiences.

Question 1 was deliberately phrased so that it did not bias the pre-service teachers toward technological, pedagogical, or content areas. For example, if pre-service teachers were unable to make connections between the technological affordances of an ICT tool and the content they were teaching, their comments related to technological content knowledge are expected to be limited. This in turn can be used as an indication of which TPACK construct was more prominent in their pedagogical reasoning. Question 2 provided data to validate the instructional methods used in each TPACK-Developing Instructional phase. There were a total of 21 groups; that is, 21 reflections collected during each class session, or a total of 63 reflections across the three sessions.

The seven categories of TPACK as defined by Mishra and Koehler (2006) were initially used to code Question 1 of the student reflections. The categories of content knowledge, pedagogical knowledge, and pedagogical content knowledge did not emerge in this study. Therefore, the final coding protocol was comprised of four TPACK categories as shown in Table 2.

The reflections were coded for the different types of TPACK constructs that emerged and were reviewed by the second author. The authors negotiated for agreement of coding to reach at least 0.80, following which the frequency of occurrence for each TPACK category was analyzed by the three TPACK-Developing Instructional phases. The relative percentages of each TPACK category were then compared across the three TPACK-Developing Instructional

Table 2. TPACK Coding Categories

TPACK construct	Coding example
a) Technology knowledge—features and functions of the Interactive Whiteboard	It has ready-to-use templates for planning activities.
b) Technological Content knowledge—knowledge of subject matter representation with the Interactive Whiteboard.	To illustrate concepts such as Water Cycle, Parts of Plants, and the Human Anatomy System.
c) Technological Pedagogical knowledge—knowledge of implementing different teaching methods with the Interactive Whiteboard.	It has interactive activities that can be used to check students' understanding.
d) Technological Pedagogical and Content knowledge (TPACK)—knowledge of using the Interactive Whiteboard in conjunction with specific teaching methods for different types of subject matter.	I can use the protractor to teach angles in Mathematics.

phases to answer the research question. Student comments for Question 2 of the reflection were used as corroborating sources of information to understand their preferred instructional methods during each phase.

Quantitative data was also collected through pre- and post-study surveys to understand pre-service teachers' level of confidence and attitudes toward the use of the Interactive Whiteboard. The tutor ensured that the Interactive Whiteboard was not introduced before the pre-study survey was administered. During week 3 of the semester, the link of the web-based pre-study survey was sent to the pre-service teachers through an e-mail which also explained the purpose of this study and sought their voluntary participation. The post-study survey was conducted during week 12 using the same process.

The pre- and post-study surveys were similar, and comprised of three parts. Part A collected information on respondent demographics (i.e., age, gender, and prior experiences with Interactive Whiteboard). Part B encompassed nine questions that assessed pre-service teachers' general confidence level for using Interactive Whiteboard for teaching—for example, I am confident I can incorporate Interactive Whiteboard in my lessons to present information. The 11 questions in Part C assessed their intentions to use the Interactive Whiteboard for support of both teacher-directed and student-centered instruction. An example of a teacher-directed use was "I intend to use the Interactive Whiteboard to help my students understand complex concepts (e.g., the water cycle more easily)" whereas an example of student-centered use was "I intend to motivate my students to use the Interactive Whiteboard to present their research results."

The questions in Parts B and C were rated using a Likert-type scale comprised of 5 points described as: (a) 1 – Strongly disagree, (b) 2 – Disagree, (c) 3 – Neutral, (d) 4 – Agree, (e) 5 – Strongly Agree. These items were reviewed by an expert panel comprised of five faculty members from the institute who specialize in the area of ICT in education. The panel recommended minor amendments for grammar and phrasing that were corrected before survey administration.

The response rates for the surveys for the pre-study was 73% ($n = 54$) whereas the post-study response rate was 36.5% ($n = 27$). The internal reliabilities of the surveys were high: Pre-study ($\alpha = 0.90$), Post-study ($\alpha = 0.95$). There was also adequate reliability for the Confidence scale in Part B ($\alpha = 0.91$) and the Intention of use scale in Part C ($\alpha = 0.91$). The response rate of the post-study survey was relatively lower than that obtained for the pre- study survey, thereby limiting the use of paired-sample *t-tests* for further statistical analysis. Therefore, only descriptive statistics were used to report the survey data.

RESULTS

The Development of Pre-Service Teachers' TPACK for Using the Interactive Whiteboard

Qualitative content analysis of the 63 reflections submitted during Phases 1, 2, and 3 derived a total of 440 comments related to the four categories of TPACK. The relative percentages of TPACK categories varied across each phase of the TPACK-Developing Instructional Model (see Figure 2).

Phase 1 – Foster Acceptance

As hypothesized, technological pedagogical knowledge was fairly significant as it comprised 33% of their reflection comments. These results showed that faculty modeling helped the pre-service teachers to formulate pedagogical strategies for using the Interactive Whiteboard. For example, the tutor had them write and organize their ideas into a mind map by using the Interactive Whiteboard's "drag and drop" function. Correspondingly, close to 44% of their technological pedagogical knowledge comments were about using the Interactive Whiteboard to consolidate students' ideas during brainstorming. The tutor also used the Interactive Whiteboard features to present her PowerPoint slides during Phase 1. As a result, close to 41% of the pre-service teachers' technological pedagogical

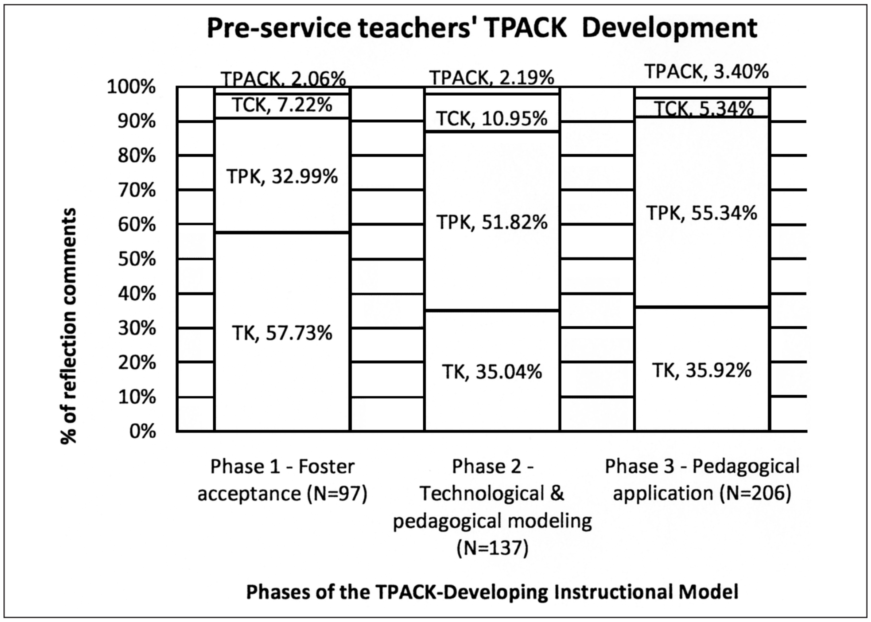

Figure 3. TPACK development across TPACK-Developing Instructional phases.

knowledge comments indicated that the Interactive Whiteboard can be used to project multimedia that stimulates the attention and interest of students. The teachers also developed new pedagogical ideas such as using the Interactive Whiteboard's annotation feature to write notes on PowerPoint slides that can be distributed to students after the class. These findings corresponded to teachers' reflection comments about how they learned to use the Interactive Whiteboard. More than half of these comments indicated that the tutor's use of the Interactive Whiteboard as an instructional tool made them interested in learning more about it.

Pre service teachers posted more comments related to technological knowledge (n = 56, 57.73%) than technological pedagogical knowledge. Their comments for technological knowledge showed an appreciation of the Interactive Whiteboard's technical affordances such as its compatibility with Microsoft PowerPoint, the ability to control the classroom computer through the touch-sensitive Interactive Whiteboard screen, and the ability to annotate directly on their projected PowerPoint slides with an Interactive Whiteboard screen. Content knowledge and pedagogical content knowledge did not emerge in their reflection comments. A possible explanation could be that these pre-service teachers were attending their first semester of teacher education courses. Their inexperience with classroom practices could have been a reason for their inability to connect technology use to pedagogical practices even though they were attending methods courses as they undertook this ICT module. Correspondingly, their technological content knowledge was comprised only of general comments about the Interactive Whiteboard being able to support multi-modal learning. A rare occurrence of TPACK mentioned using the annotation feature for teaching the writing sequences of Chinese words.

Phase 2 – Technological Proficiency and Pedagogical Modeling

As hypothesized, the category of technological knowledge was fairly prominent during the second phase of the TPACK-Developing Instructional Model because it comprised about 35% of the students' reflection comments. The pre-service teachers commented that they learned how to use Notebook, a software program for developing Interactive Whiteboard presentations, from both the tutor's demonstration and their hands-on exploration. Examples of technological knowledge they had acquired were the procedures for creating "drag and drop" activities and game-based interactive quizzes. Their technological knowledge for handling the Interactive Whiteboard board (e.g., how much pressure should be applied when using the Interactive Whiteboard pen to annotate) was also enriched through hands-on exploration.

Pre-service teachers' hands-on exploration of the Notebook software and the Interactive Whiteboard board during Phase 2 also helped them develop technological pedagogical knowledge which was reflected in a sizeable 52% of their reflection comments (see Figure 2). As compared to Phase 1, their Phase 2 technological pedagogical knowledge comments showed a larger variation of pedagogical ideas with respect to the use of Interactive Whiteboard. Some examples of these included using the Interactive Whiteboard to support frontal teaching, using quiz games to stimulate conversation with students during recap and revision, and promoting active learning by having students come up to the Interactive Whiteboard to "drag and drop" answers to the quiz games. Their technological pedagogical knowledge was also enriched by an awareness of practical problems involved when teaching with the Interactive Whiteboard. Some examples were the need to maneuver their standing position to avoid casting a shadow on the projection board, and the need to consider if students were tall enough to reach objects designed for "drag and drop." Interestingly, in every reflection submitted, pre-service teachers commented that they preferred to explore the Interactive Whiteboard together with their peers. A learning strategy employed by most groups was to have each person focus on exploring a specific aspect of the tool before sharing new discoveries and pedagogical ideas with each other.

Although the pre-service teachers reviewed an online tutorial which guided them to explore a database of subject-specific Interactive Whiteboard examples, the relative percentage of comments associated with technological content knowledge and TPACK only increased slightly during this phase. Analysis of their reflection comments related to technological content knowledge found statements that mirrored the examples in the database such as using the Interactive Whiteboard resources to visualize complex concepts in a subject-area. There were also more instances of TPACK where specific Interactive Whiteboard functions were related to teaching content (e.g., using the anagrams quiz template to introduce new vocabulary to students and using the word-match game for English). Nevertheless, the proportion of comments related to technological content knowledge and TPACK were still substantially lower than those for technological knowledge and technological pedagogical knowledge.

Phase 3 – Pedagogical Application

While the pre-service teachers' participation in design activities was envisioned to help them develop TPACK, the study results showed them predominantly developing technological pedagogical knowledge during Phase 3 (55.34%). However, analysis of their technological pedagogical knowledge comments found that the experience of designing Interactive Whiteboard-integrated lesson activities helped them better articulate the reasoning behind their pedagogical conceptions for using the Interactive Whiteboard. With respect to using the quiz templates for recap and revision, they felt that this not only tested the understanding of students who were called to answer the questions, but it also provided opportunities for other students in the class to learn from their peers' mistakes. The pre-service teachers also developed new types of technological pedagogical knowledge which encompassed the classroom management strategies for an Interactive Whiteboard lesson. For example, they took into consideration if the font-size and colors selected for an Interactive Whiteboard slide were appropriate when projected.

The relative percentage of technological knowledge comments was about 36%, which was close to that obtained during Phase 2. However, Phase 3 technological knowledge comments showed evidence that pre-service teachers gained more knowledge about the Interactive Whiteboard Notebook software during their Interactive Whiteboard lesson sharing session. Some examples were the full screen function, and the insertion of pictures, videos and web addresses. They also learned about potential technical problems associated with using the Interactive Whiteboard software. Examples of such technical problems are the limitations for adjusting font-size and type when using some templates on and how to save pictures into a template without losing them. This corresponded to their reflection comments which cited peer sharing as a factor that helped them to learn more about the Interactive Whiteboard and its features.

As compared to Phase 2, the relative percentage of technological content knowledge was lower (5.34%) but TPACK was higher (3.40%). Analysis of the Phase 3 technological content knowledge comments did not find them substantially different from Phase 2 as these were also about using the Interactive Whiteboard functions to better represent concepts. Their TPACK, however, was different. The pre-service teachers commented on the difficulty of matching the Interactive Whiteboard quiz templates to the needs of their content area. They also found it difficult to conceptualise how some templates designed for a particular subject area could be adapted to teach another subject.

Pre-Service Teachers' Confidence and Attitudes toward Using the Interactive Whiteboard

The pre-study survey showed that the pre-service teachers were neither confident nor unconfident of their ability to teach with the Interactive Whiteboard (pre-study confidence: $M = 3.40$, $SD = 0.58$). Their confidence for teaching with the Interactive Whiteboard appeared to have increased after undergoing the lessons prescribed by the TPACK-Developing Instructional approach (post-study confidence: $M = 3.93$, $SD = 0.53$).

Interestingly, the pre-study survey found that pre-service teachers indicated fairly strong intentions to use the Interactive Whiteboard when they become a full-fledged teacher (pre-study intention for Interactive Whiteboard use: $M = 3.95$, $SD = 0.40$). Therefore, the post-study survey found the changes in their intentions of use to be negligible ($M = 3.94$, $SD = 0.53$).

DISCUSSION

This study found that the three phases of the TPACK-Developing Instructional model were effective for enhancing the confidence of pre-service teachers to integrate a new ICT tool. Their interest to integrate the Interactive Whiteboard into their future teaching practice was already high at the beginning of the study and was still consistently high at the end of the study. One possible explanation could be due to the novelty effect of the Interactive Whiteboard. Second, it could be because the Interactive Whiteboard was perceived as a conventional whiteboard, which is a standard part of the classroom. Hence, pre-service teachers perceived it to be a plausible ICT tool. Qualitative analysis of their reflection comments found that they were more concerned with making sense of the Interactive Whiteboard's technical capabilities as a user during Phase 1, which explained the predominance of technological knowledge comments. On the other hand, their technological pedagogical knowledge during Phase 1 largely mirrored the content of faculty modeling. During Phase 2, they started to think about technology use as teachers, as can be seen from the predominance of technological pedagogical knowledge comments. Their hands-on experiences with the Interactive Whiteboard and sharing with peers helped them to develop many pedagogical ideas which went beyond what the tutor was able to model. While the design activity in Phase 3 was envisioned to help them develop TPACK, it appeared that this was more effectual for deepening their technological knowledge and technological pedagogical knowledge. Even though they were provided with subject-based models of Interactive Whiteboard use, instances of technological content knowledge and TPACK were still fairly limited. This could be due to following reasons.

Pre-Service Teachers' Profile

Angeli and Valanides (2009) found the nature of TPACK to be transformative because it is a unique body of knowledge synthesized from the integration of technological knowledge, content knowledge, and pedagogical knowledge. While novice-expert comparisons have not been made in TPACK studies, earlier studies in the area of pedagogical content knowledge found that novice teachers considered content and pedagogy separately when envisioning lesson agendas. In contrast, expert teachers were able to make better linkages between the two (Copeland, Birmingham, DeMeulle, D'Emidio-Caston, & Natal, 1994; Leinhardt, 1989; Sabers, Cushing, & Berliner, 1991). The pre-service teachers in this study were attending their first semester of teacher education training. Therefore, it is possible that they were still in the process of making connections between technological knowledge, pedagogical knowledge, and content knowledge. They were able to develop technological pedagogical knowledge through this instructional intervention whereas further exposure to methods courses throughout their teacher education program may be needed before they are able to further develop technological content knowledge and TPACK.

Course Design

This ICT module was conducted in conjunction with methods courses. The module thus focused on the pedagogical uses of technology while the methods courses focused on pedagogical content knowledge. Unlike experienced teachers who have more knowledge of school practices, the need to connect technology with content may not be instinctive for the pre-service teachers. Therefore, the pre-service teachers may benefit from exploring more lesson activities to help them make the connection between technology use and pedagogical practices.

TPACK as Long-Term Development

The adoption of an unfamiliar ICT tool could span across a period of time-range during which teachers grapple with issues of technology familiarization, utilization, and integration (Dalton, 1989; Dwyer, Ringstaff, & Sandholtz, 1991; Moersch, 1995). Niess et al. (2006) studied 11 teachers' integration of an ICT tool and found that the majority only attained Stage 3 of the TPACK development process after attending an ICT course and undergoing a year-long mentoring program. Despite being exposed to the Interactive Whiteboard for 7 weeks, the pre-service teachers in this study consistently generated and deepened their technological knowledge and technological pedagogical knowledge. A long-term trajectory toward TPACK development needs to be considered because teachers could require long periods of continual exposure to ICT tools to gain confidence in technology integration (Albion, 2001; Milbrath & Kinzie, 2000). TPACK may therefore be more predominant for in-service teachers rather than pre-service teachers.

IMPROVEMENTS TO THE TPACK-DEVELOPING INSTRUCTIONAL MODEL

The above discussion shows that the pre-service teachers need to first be comfortable with ICT as users before they are ready to use it as teachers. Pre-service teachers' attitude formation also goes hand-in-hand with their technical proficiency. Therefore, it is proposed that Phase 1 of the revised TPACK-Developing Instructional model should focus on fostering their attitudes and technical proficiency (see Figure 3). Faculty modeling of the ICT tool through day-to-day use and demonstrations of the tool's technical affordances are the instructional methods recommended. Peer sharing of technical skills can also be used to support the development of technical proficiency as it emerged in this study as an effective learning strategy for the pre-service teachers. This is consistent with research findings that teacher professional development occurred through peer learning, peer collaboration, and the observation of each others' ICT-integrated lessons (Blase & Blase, 1999; Divaharan & Koh, 2010; Flanagan & Jacobsen, 2003; Jacobsen, 2001, 2002; Prain & Hand, 2003).

Pre-service teachers in Singapore being trained for primary and secondary education attend their ICT course module in different sections. However, teachers specialized in a range of teaching subjects within each section. It could be challenging for the tutors to model content-based integration examples. Therefore, it is proposed that a concerted effort be made to build a repository of subject-based lesson plans that can be provided to pre-service teachers. During lessons, they should be grouped by related subject specializations and be asked to critique and improve ICT-integrated lesson plans related to that area. Creating a community of practice among teachers helps them sustain learning (Davis, Preston, & Sahin, 2009; Divaharan & Lim, 2010). Such activities can also help them to develop pedagogical reasoning (Shulman, 1999) as they form connections between technological, pedagogical, and content knowledge. Going beyond this ICT module, more subject-based modeling could also be carried out during methods course as a stand-alone ICT course may not fully address pre-service teachers' TPACK development needs.

CONCLUSION

This study found that TPACK-developing ICT courses need to encompass the aspects of confidence building, subject-focused pedagogical modeling, and

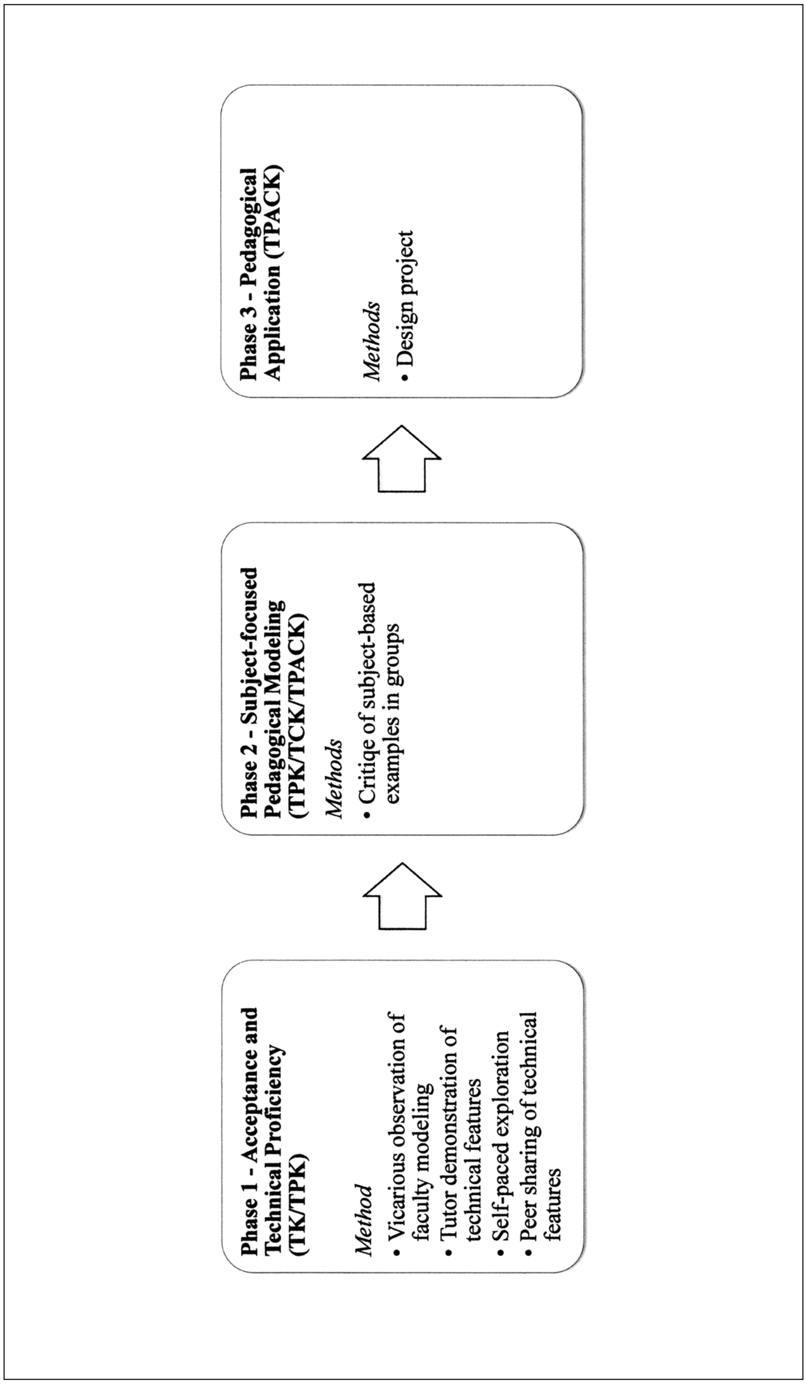

Figure 4. Revised TPACK-Developing Instructional Model.

hands-on application. The three-phase process of the proposed TPACK-Developing Instructional model were effective for enhancing pre-service teachers' confidence toward making pedagogical use of an unfamiliar ICT tool. However, pre-service teachers' TPACK can be effectively developed through subject-focused pedagogical modeling and peer sharing of ICT integration ideas.

While the described intervention was only implemented with three classes of 74 pre-service teachers, it would be useful to observe its effects on more pre-service and in-service teachers teaching different subject specializations and class levels. The intervention was also limited to the use of the Interactive Whiteboard as an instructional tool. Further research needs to be conducted to validate this approach for the instruction of different types of ICT tools. In addition, the TPACK-Developing Instructional Model was designed for the instruction of ICT tools that are new and unfamiliar to teachers. It could be that Phase 1 of the model may not be applicable when teachers are learning the pedagogical uses of ICT tools that they are already familiar with. This aspect needs to be further examined in future research. A follow-up study can contribute toward developing generalized principles and models for the instruction of ICT tools that effectively develop the TPACK or technology integration expertise of pre-service teachers.

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