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Integrating the interactive whiteboard and peer coaching to develop the TPACK of secondary science teachers

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ABSTRACT

Many studies related to the use of interactive whiteboards (IWBs) in educational settings have shown that IWB technology can result in enhanced presentations and in the development of student motivation and student performance. However, the relationship between the use of IWBs and Technological Pedagogical Content and Knowledge (TPACK) by teachers is yet to be fully investigated and understood. The purpose of this study was to integrate IWB technology and peer coaching to develop the TPACK of secondary science teachers in real classrooms. An IWB-based peer coaching model was developed. Participants of this study included four in-service science teachers. The sources of data included written assignments, reflective journals and interviews. The results displayed three major findings. First, science teachers used IWBs as instructional tools to share their subject-matter knowledge and to express students' understanding. Second, the IWBs helped the science teachers who encountered teaching difficulties in the traditional classroom better implement their representational repertoires and instructional strategies. Finally, the proposed model of integrating IWBs and peer coaching can develop the TPACK of science teachers. The research implications of this study are provided along with suggestions.

1. Introduction

One criticism of school-based instruction is the use of outdated teaching methods and contents to equip current students for future society (Jang, 2009a). Science teachers in the 21st century need to be equipped with professional teacher knowledge, which has been referred to as Technological Pedagogical Content Knowledge (TPCK). This implies that teachers have the ability to apply technology into their pedagogical strategies and content representations for teaching specific topics to promote students' learning efficiency (Mishra & Koehler, 2006; Niess, 2005). The TPCK framework builds on Shulman's (1986, 1987) construct of Pedagogical Content Knowledge (PCK) to include technological knowledge as situated within content and pedagogical knowledge (Mishra & Koehler, 2006). Furthermore, the TPCK framework not only expresses the importance of technological integration but also introduces the relationships and the complexities between all three basic components of knowledge (technology, pedagogy, and content). However, rather than treating these as separate bodies of knowledge, TPCK is the integration of the development of subject-matter knowledge with that of technology and of teaching and learning knowledge (Jang & Chen, in press; Niess, 2005).

Many studies have been undertaken to investigate the use of interactive whiteboards (IWBs) in classroom environments. They have focused primarily on the use of IWBs in increasing student motivation (Glover, Miller, Averis, & Door, 2007; Hall & Higgins, 2005; Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Higgins, Beauchamp, & Miller, 2007; Schmid, 2008; Slay, Sieborger, & Hodgkinson-Williams, 2008). In 2006, the Ministry of Education in Taiwan provided the impetus to build e-learning environments for secondary and primary schools, and continually set up IWBs as part of the technological facilities. However, some teachers are afraid of changing, and still use the traditional teaching media which they are familiar with. They lack not only the understanding of the technological IWB facilities, but also practice using the related supports of IWBs (Kent, 2006; Smith, Higgins, Wall & Miller, 2005). However, many studies have shown that teachers point out the efficiency, flexibility and versatility of IWBs and the opportunity to access multimedia content, as well as the ability to

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manage the class more easily by using an IWB (Smith et al., 2005). It seems clear that many teachers have found IWB-supported planning to be an important and highly motivating teaching resource (Gillen, Littleton, Twiner, Staarman, & Mercer, 2008; Holmes, 2009; Loveless, 2003; Warwick & Kershner, 2008).

Individual teachers may encounter some difficulties while applying the new technology. Science teachers should cooperate with others through teamwork instead of working alone (Jang, 2008). Peer coaching provides a community of practice to be defined as a group of individuals who share such commonalities as interests, knowledge, resources, experiences, perspectives, behaviors, language, and practices (Jang, 2009b; Lave & Wenger, 1991). Bowman and McCormick (2000) suggested that through social interaction, active learning evolves and each participant interprets, transforms, and internalizes new knowledge. Within the framework of peer coaching, such collaborative discussions allow individuals to develop their own perspectives and to model strengths for others. Peer coaching can be described as a collegial approach to the analysis of teaching aimed at integrating new skills and strategies in classroom practice (Joyce & Showers, 1995).

Numerous studies related to the use of IWBs in educational settings (particularly in mathematics) have shown that IWB technology can result in enhanced presentations and in the development of student motivation (Glover et al., 2007; Torff & Tirotta, 2010), and student performance (Arcavi, 2003; Lopez, 2010; Sedig & Liang, 2006). However, it would appear that the relationship between the use of IWBs and the TPCK of teachers is yet to be fully investigated and understood, particularly for science teachers (Gillen et al., 2008). Therefore, the purpose of this study was to integrate IWB technology and peer coaching to develop the TPCK of secondary science teachers in real classrooms.

2. Theoretical framework

2.1. Technological pedagogical and content knowledge

TPCK highlights the connections and interactions among content, pedagogy, and technology (Mishra & Koehler, 2006). Koehler, Mishra, and Yahya (2007) stated that TPCK is a situated form of knowledge required for the intelligent use of technology in teaching and learning. Thompson and Mishra (2008) proposed to rename the acronym TPCK as TPACK (pronounced “tee-pack”) for the purpose of making it easier to remember and to form a more integrated whole for the three kinds of knowledge addressed: technology, pedagogy, and content. Furthermore, the complex among the three kinds of knowledge was reframed as TPACK, describing it as the total package required for integrating technology, pedagogy and content knowledge in the design of curriculum and instruction (Niess et al., 2009; Thompson & Mishra, 2008). TPACK represents a new direction in understanding the complex interactions among content, pedagogy and technology that can result in successful integration of technology in the classroom. TPACK is an extension of PCK and is primarily achieved when a teacher knows how technological tools transform pedagogical strategies and content representations for teaching specific topics. Therefore, science teachers reemphasized the importance of these three kinds of knowledge integration so that teachers can attain a whole knowledge system to help students promote their learning.

Koehler et al. (2007) reported on the results of a semester-long investigation of the development of TPACK during a faculty development design seminar, whereby faculty members worked together with master students to develop online courses. A quantitative discourse analysis of 15 weeks of field notes for two of the design teams showed that participants moved from considering technology, pedagogy and content as independent constructs towards a richer conception that emphasized connections among the three knowledge bases. Hence, through the collaboration of science teachers might gain deeper understandings of the complicated relationships between content, pedagogy and technology that functioned in the peer coaching context.

Graham, Burgoyne, Cantrell, Smith, St. Clair, and Harris (2009) also designed a survey to measure in-service science teachers’ TPACK confidence. They developed a pre–post questionnaire which included 31 questions and two open-ended questions to measure in-service teachers’ confidence related only to the four TPACK constructs that involve technology. The results also suggested the instrument was useful in helping the program coordinators to see significant increases in the TPACK confidence of participants over the eight-month duration of the program. However, Graham et al. (2009) focused on quantitative data collection and analysis limited to portraying the context of science teaching and learning. They also neglected to mention that a deep knowledge of science content is also an essential ingredient in the teaching mixture of technology, pedagogy and content knowledge bases.

Angeli and Valanides (2009) proposed five indicators for pre-service teachers to assess TPACK in designing instruction with technology: (a) Identification of topics to be taught with technology in ways that signify the added value of tools, such as topics that students cannot easily comprehend, or topics that teachers face difficulties in teaching effectively in class; (b) Identification of representations for transforming the content to be taught into forms that are comprehensible to learners and difficult to support by traditional means; (c) Identification of teaching strategies, which are difficult or impossible to implement with traditional means; (d) Selection of appropriate computer tools and effective pedagogical uses; and (e) Identification of appropriate strategies to be combined with technology in the classroom, which include any strategies that put the learner at the center of the learning process.

While the five indicators provide related rich examples related to teaching, there are few specific subject examples of students’ background knowledge and the application of teaching strategies. Concrete examples of scientific topics could help to better describe the interaction among all the elements in TPACK.

2.2. Using interactive whiteboards to develop teacher’s TPACK

IWBs are large, touch-sensitive boards that control a computer connected to a digital projector, allow the user to prepare material in advance or construct it in front of a class, quickly retrieve it for display to the whole class when required and manipulate items directly on the display (Kennewell, Tanner, Jones, & Beauchamp, 2008). In related studies, IWBs are considered as tools that enhance teaching and support learning. As a tool to enhance teaching, the use of IWBs supports teachers’ planning and development of resources and allows teachers to model appropriate technology skills for the students. They also improve interactivity and student participation in lessons (Smith et al., 2005). It has also been reported that the efficiency, flexibility and versatility of IWBs as teaching tools allow teachers to support multiple needs within one lesson (Miller & Glover, 2002; Smith et al., 2005).

As a tool to support learning, Wall, Higgins, and Smith (2005) found that learners saw IWBs as effective tools for initiating and facilitating the learning process, particularly when they were given the opportunity to use the IWB themselves. The learners also commented on the visual nature of the IWB, frequently referring to the different ways information can be presented which was seen as a way to reinforce concentration and attention. Smith et al. (2005) have provided an excellent review of studies discussing the impact and the potential of IWBs. There is insufficient evidence to identify the actual impact of such technologies upon learning either in terms of classroom interaction or upon attainment and achievement. This article examines this issue in light of varying conceptions of interactivity and research into the effects of learning with verbal and visual information. Higgins et al. (2007) also examined the impact of IWBs on student learning, as measured by standardized assessments.

Gillen et al. (2008) used a case study to examine in detail how a teacher pursued two themes across four science lessons. They examined how the science teacher created continuity in her students' learning experiences through taking advantage of some of the functions of the IWB in order to represent scientific phenomena and engage children in activities to consolidate their understandings. Smith, Hardman, and Higgins (2006) set out to investigate the impact of IWBs at an elementary school. They found that pace was faster when using the IWB, and there were more open questions and interactivity. They concluded that, by itself, such technology will not bring about fundamental change in the traditional patterns of whole class teaching; however, more reciprocal forms of teaching can come about to support teachers in their professional development.

Studies of both IWBs and TPACK have discussed technological integration (Harris, 2008; Kent, 2006). The key to integration is that science teachers can integrate pedagogical content knowledge, technological knowledge and students' related knowledge into their TPACK. However, previous TPACK quantitative measures have been relatively weak in portraying the subtle interrelationships among technology, pedagogy and content in the context of science teaching and learning. Furthermore, the quantitative measures have hardly been used to assess and describe how science teachers develop their TPACK. Therefore, in this study, the researcher transformed Angeli and Valanides (2009) five criteria into written assignments for assessing the development of TPACK for secondary science teachers, and used a multi-method approach and qualitative in-depth study to develop a model of integrating IWB technology and peer coaching to examine the impact on the TPACK of secondary science teachers.

2.3. Peer coaching

A community of peers is important not only in terms of support but also as a crucial source for generating ideas and providing criticism (Davis, 1987; Sykes, 1996). Pierce and Hunsaker (1996) stated that peer coaching not only increases collegiality, but also enhances each teacher's understanding of the concepts and strategies of teaching, and sustains the movement toward restructuring traditional evaluation efforts by strengthening the ownership of change. Jenkins, Garn, and Jenkins (2005) suggested peer coaching as a means of developing PCK because of its real-life context in which teaching and learning occur. Peer coaching can increase reflective practice, aid implementation of teaching models and instructional strategies, and enhance classroom management and development of PCK (Jenkins & Veal, 2002; McAllister & Neubert, 1995). Joyce and Showers (1982, 1995) also introduced peer coaching as a component of in-service teacher training. Their fully elaborated in-service peer coaching model with a planning and implementation focus consists of four elements: (1) the study of the theoretical basis or rationale of the teaching method, (2) the observation of demonstrations by persons who are experts in the teaching method, (3) practice and feedback in relatively protected conditions, and (4) coaching one another to allow the new method to be incorporated into day-by-day teaching style. In their more recent work, Joyce and Showers (1995) expanded their view of peer coaching, emphasizing learning through collaborative planning, development and observation of instruction. They stressed the importance of a non-hierarchical relationship between peers working and learning collaboratively to improve their teaching.

2.4. Developing an IWB-based peer coaching model for TPACK

Shulman (1987) proposed that PCK development might pass through the processes of comprehension, transformation, instruction, evaluation, reflection and new comprehension. This study integrated instructional process and peer coaching (Joyce & Showers, 1995) into the IWB-based model of TPACK–COIR (TPACK Comprehension, Observation, Instruction and Reflection) as shown in Fig. 1. This model comprises four main activities: (1) Comprehension of TPACK, (2) Observation of peer instruction, (3) Instruction of a real class, and (4) Reflection of TPACK. The IWB technology was integrated to fully implement the TPACK–COIR model.

First, the integrative model starts with the study of the theoretical basis or rationale of the specific content teaching method. This includes study on the topics of textbooks and TPACK articles in teams, and understanding of the implementation and functions of the IWB hardware and software. Each teacher describes his/her understanding of the subject-matter knowledge of the specific subject content unit. The analyses and discussions on these PCK and TPACK research articles also contribute to the teacher's PCK of useful instructional strategies for overcoming students' learning difficulties (Jang, 2009b; Van Driel, De Jong, & Verloop, 2002) or identifying some topics which are difficult to implement by traditional means. Second, in order to integrate TPACK theories and practice, the second main activity involves observation of experienced peer teachers using IWB technology. Participants should observe teaching and note skills according to the TPACK theories and strategies they have learned. After watching the demonstration, science teachers take turns to give their comments and suggestions. Third, science teachers learn to design IWB technology-based lesson plans and apply them in their classrooms. Some related studies have indicated that design and teaching experience are important for TPACK development (Jang & Chen, in press; Koehler et al., 2007). All of lessons about the chosen topics that took place during the teaching of classes were video-recorded. Finally, each teacher should show the videotapes of his/her teaching to share his/her teaching experience with others. This teaching experience can stimulate teachers' self-reflection (Vidmar, 2006). This study used an integrative model by combining IWB technology and peer coaching to develop the TPACK of science teachers.

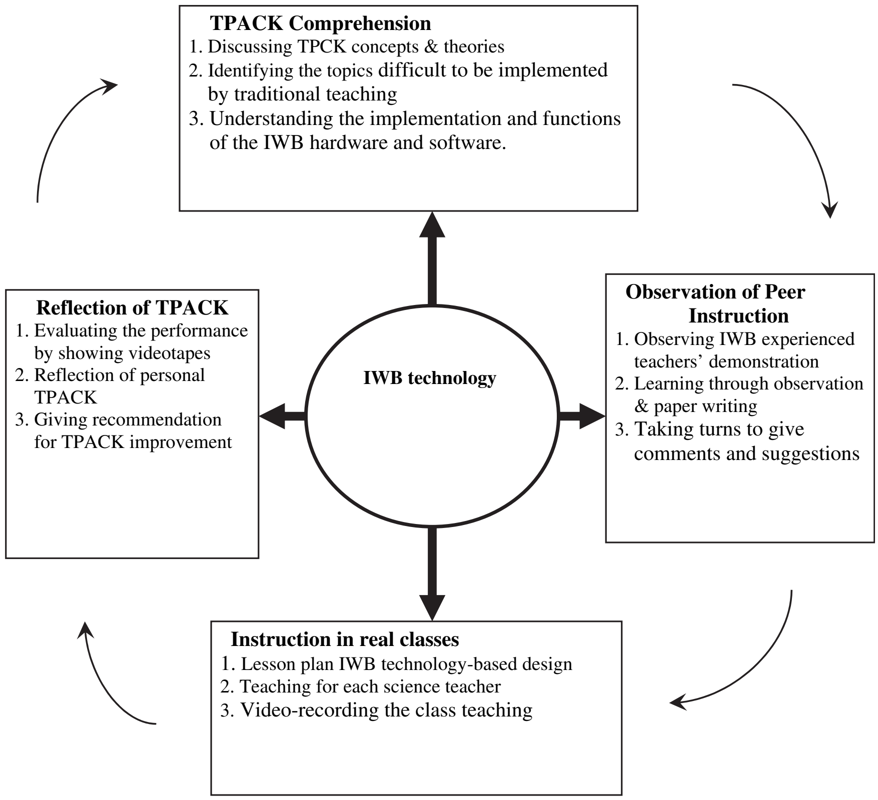

Fig. 1. An IWB-based model of TPACK–COIR.

3. Research methodology

3.1. Participants

In order to avoid any misunderstanding or inefficient communication that might have yielded biased results, one participant was found with whom the researcher could conduct the study and communicate easily. Then, this participant looked for other teachers whom she could trust to become partners for peer coaching. The researcher formed a peer-coaching team with four science teachers who teach eighth-grade students in a secondary school in Taoyuan County, Taiwan. The secondary students were seventh to ninth-grade junior high school students. These four science teachers were all enthusiastic about teaching and gaining new knowledge. Moreover, they were all willing to make changes.

This study refers to four science teachers using names that are different from their real names. Female names, however, refer to female teachers and male names to male teachers. Teacher Amy had a degree in Chemistry. She had ten years teaching experience, and had just begun to learn IWB technology. She had the desire to learn new teaching methods and know students' learning performances. Teacher Bee also had a degree in Chemistry. She had five years teaching experience and sometimes used IWB technology to teach her classes. She was interested in teaching and creating new teaching methods. She liked discovering and discussing the learning difficulties faced by students. Teacher Caleb majored in Physics. He had 12 years of teaching experience and had just begun to learn IWB technology. He was a strict person, one who calls a spade a spade and rarely loosens up in class. Teacher Dick majored in Earth Science and had taken some courses in Technology. He had three years of teaching experience, and had enjoyed teaching science using IWB technology for more than one year.

One of the classes of each teacher was selected for this study. The selection was based on the following factors: class size and teacher's intention. The numbers of students in each class were 32, 31, 28, and 30. The numbers of students totaled 121. Because the researcher was restricted by the original class placement of students done by the school according to a normal S distribution, the subjects were chosen through non-random sampling. Students at this level were willing to express their own opinions and ask questions concerning the teaching contents.

3.2. Research design and implementation

The research design was to implement the IWB-based TPACK–COIR model (see Fig. 1) for one semester. The research was conducted from September 2009 to January 2010. Peer-coaching meetings were held once every two weeks. In this study, the researcher chose the topic of "Heat and Temperature", because students' conceptions of this topic are at odds with those of scientists (Paik, Cho, & Go, 2007). The four activities of the TPACK–COIR model were integrated into the whole process through four stages as discussed below.

3.2.1. Stage one: TPACK comprehension

The first four week meeting discussed the main activity for understanding the content of TPACK. The researcher allowed the science teachers to study the content of TPACK in teams. In order to facilitate the official implementation of IWB technology, science teachers should become familiar with the implementation and functions of the hardware and software and reinforce the support in either hardware or software to prevent possible technical problems.

In this stage, each science teacher described his/her understanding of the subject-matter knowledge of the specific subject content unit in his/her journal. After the group discussion, they noted the contents of students' understanding and preconceptions of these topics. During the first stage, they were asked to answer the following question:

> Assignment 1: From your previous teaching practice, what difficulties have you encountered in learning the concepts of "Heat and Temperature"?

The science teachers wrote down their recollections individually, which were then discussed by all. After the discussion and examination in a group, they wrote down their responses in their reflective journals.

3.2.2. Stage two: observation of peer instruction

In order to learn more TPACK theories and practice from Week 5 to Week 6, the second main activity was to have Teacher Dick demonstrate his teaching of integrating IWB technology with respect to the unit – "Heat and Temperature". After watching the teaching demonstration, the science teachers took turns to give their comments and suggestions, and the researcher then gave his comments. For example, Dick used IWB to show a flash file and ask a question to stimulate students' learning motivation. The question was "What is heat?" Students were asked to think individually, then discuss in small groups, and finally to answer the question on the IWB. This provided a good teaching strategy for other science teachers to learn in this study. At this stage, the science teachers were asked to write down their individual responses to the following assignment:

> Assignment 2: What teaching representations or strategies for understanding "Heat and Temperature" might you use to transform science content into forms that are pedagogically powerful?

Again, all written responses were collected, and the subsequent group discussion was recorded in their reflective journals.

3.2.3. Stage three: instruction and video recording

The third activity was carried out from Week 7 to Week 15. Each teacher selected an appropriate teaching strategy or representation to integrate the IWB technology design according to the knowledge acquired from the study of relative references or books. Teachers implemented the teaching design in their own classes. They might have integrated the previously learned TPACK strategy and skills by observing the teaching of the demo teacher. For example, the topic Teacher Amy taught was the fundamental concepts of 'Heat'. She operated IWB to show a chart and the methods of "heat conduction" and asked students to observe and discuss. The entire teaching session was video-recorded to serve as a reference for mutual observation, learning and reflection in peer coaching. In addition, they wrote down their own thinking and raised questions in the reflective journals.

3.2.4. Stage four: TPACK reflection

The fourth activity, involving reflection and modification, lasted from Week 16 to Week 18. After they finished teaching their lessons, the researcher and the science teachers came together to view the videotapes of their teaching. The science teachers shared their teaching experiences with each other, and wrote down their reflections in their journals. The purpose of this activity was to evaluate their teaching performance. In this stage, the teachers evaluated the effects of the integration process on TPACK and the ability of the various science teachers to take advantage of technology. When evaluating the TPACK development, special attention was given to *how* they integrated content, pedagogy, and technology in a course topic, as well as *why* they decided to implement such integration.

> Assignment 3: (a) How do you use IWB technology with pedagogy to afford content transformations of these topics? Describe your TPACK development after you went through the whole process of the model?

Again, all written responses were collected, and the subsequent group discussion was recorded in their reflective journals.

3.3. Data collection and analysis

The data collected consisted of: (1) the written assignments of each individual science teacher to the questions and assignments included in the four parts of the model; (2) the reflective journal written by the science teachers through the overall process of the model; and watching the video-recordings of lessons about the chosen topics that took place during the class teaching; and (3) the interviews which served to gain a deeper understanding of each teacher's conceptions.

The interviews were conducted after implementing the model. Their purpose was to explore the extent of the transformation of each science teacher's TPACK. The interviews included the understanding of learner's knowledge, the changes in teaching knowledge or skills, the ability to implement technologies, and the overall changes in TPACK. According to the information gathered from the interviews, the researcher attempted to discern the possible discrepancies of their views written down in their written assignments and journals. Inductive data analysis was employed in this study by utilizing a qualitative framework that allowed the researcher to build patterns of meaning from the data (Patton, 1990). The process of analyzing the qualitative data consisted of the following three steps: (1) coding and developing temporary coding categories; (2) adopting the constant comparative process; and (3) defining categories and producing assertions. Accordingly, the researcher assigned the changes discovered in individual respondents to these categories, resulting in a numerical overview of the results. A constant comparative method was utilized to compare the written assignment data and other data with the categories generated (Strauss, 1987). The data were first collected, coded, compared and then organized into different categories. Then the data were interpreted according to the categories.

4. Results

According to the research purpose and the following written assignments, the results were divided into the following three categories.

4.1. *Science teachers used IWBs as instructional tools to share their subject-matter knowledge and to express students' understanding*

Science teachers adopted IWBs as primary tools for explaining concepts and focused on the subject content and the transmission of concepts. Teachers seldom used group discussion, but they used the traditional teaching strategies such as lectures. Teachers showed confidence with their PCK, and they rarely paid attention to how the subject-matter could be related to everyday life or how the science concepts could be applied to situations in life. They also adopted IBWs as tools for students to interpret questions. Students were able to present their thoughts with IWBs. During break time, science teachers let students who were interested in the IWBs play interactive games. They hoped students could operate the stylus more often and become familiar with the functions. The opinions of the four teachers are as follows.

Ipreferred using mathematic formulas to explain the concepts of "heat and the process of floating". Owing to the lack of time, I rarely provide examples from everyday life. (Caleb's written assignment, 2009/09/16)
Iadopted an IWB as the main tool for explaining concepts. For example, thermal convection involves transmission of heat energy from high to low temperature. However, my lesson lacked discussion between the teacher and students. (Bee's interview, 2010/01/20)
In order to get students interested in the IWB, I used break time to let them play interactive games using the IWB. (Amy's interview, 2010/01/20)
I used the IBW as a tool for students to interpret questions such as how come the process of heat transmission requires no medium? Students were allowed to present their thoughts on the IWB. (Dick's written assignment, 2009/12/23)

4.2. *IWBs help science teachers who have difficulty implementing representational repertoires and instructional strategies in traditional classrooms*

Their science teachers used simple and easy instructional representations in traditional classroom settings. They utilized tables and analogical arguments as well as lectures and writing on the blackboard when explaining concepts. When the students were required to attend lectures, take notes and practice solving problems, there was less mutual communication between teachers and students. However, concerning teaching strategies and representations, this study shows that science teachers can adopt IWB technology to present teaching strategies and representations appropriately. Science teachers can also offer opportunities for students to present and explain questions by using the IWBs.

"Specific heat capacity" is a new concept for students. When I explain it the first time, I usually draw a picture instead of using other tools. Now I can use the IWB to explain the concept. (Bee's reflective journal, 2009/10/22)
I encourage students to present their ideas on the IWB. I give them appropriate feedback after the presentation. (Amy's interview, 2010/01/20)
The way I taught this topic before was to have students attend the lecture and take notes in class for the whole semester. I didn't prepare stories or videotapes as extra teaching tools. (Caleb's reflective journal, 2010/01/07)
Students are not clear about the concept of "specific heat capacity", so I used the IWB to show a flash file for the analogical example of temperature to clarify the heat of water. When the same quantity of water goes into a glass cup of a narrow size, the water level rises easily. The phenomenon is analogical to the rise of temperature. (Dick's written assignment, 2009/12/23)

4.3. *The model of integrating IWBs and peer coaching can develop the TPACK of science teachers*

The science teachers comprehended the operation of IWB through peer coaching and sharing. Considering the difficulty of the scientific content of "heat and temperature", IWBs became transformative and demonstrative tools used to simplify the difficult concepts in order to help students understand the topic better. Therefore, the science teachers can apply IWB resources such as e-books, story animation, and the Internet to teaching and learning. Animation stimulates students' learning motivation, e-books help students control the themes better, and website resources can integrate experimental activities. Meanwhile, the science teachers in this study were the most appropriate reflective coaches for each other, because they could faithfully reflect their observations on teaching practices. In this regard, when the teachers provided feedback to each other, they not only gave suggestions but also positive feedbacks in order to facilitate their peers' teaching skills and strategies. Science teachers should be more open to critical suggestions for improvement and changes offered by supportive peers.

My teaching method and pattern lacked change before. Now I can use e-books in my teaching strategies to help students understand the main part of the content more easily. (Caleb's interview, 2010/01/20)
The teaching schedule and the pressure of examinations are the main obstacles for innovative teaching. However, I adopted story animation to stimulate students' motivation in my class. (Bee's written assignment, 2009/10/14)
I used website resources to integrate the experimental activities of "heat and temperature" into IWB teaching. I learned viewpoints from peer coaching. (Amy's reflective journal, 2009/11/25)
Peer coaching requires the teachers to be open-minded to both positive and negative feedback from peers. Positive feedback can enhance their teaching skills while negative feedback can modify their teaching. (Dick's reflective journal, 2009/12/09)

5. Discussion

Different from the other studies of students' motivation toward IWBs, the main contribution of this study was to help science teachers develop their TPACK using IWBs. According to the findings, science teachers used IWBs as instructional tools to display their subject-matter knowledge, particularly in the topics that students cannot easily comprehend in traditional classes. Science teachers learned how to present the concepts of "heat and temperature" by using IWBs. This trains science teachers to integrate IWB technology and content knowledge into their TPACK. Koehler et al. (2007) proposed the concepts of TPACK and clearly identified the function related to technology. However, they neglected to mention that a deep knowledge of science content is integrated into technology. Previous studies have failed to portray the subtle interrelationships among technology, pedagogy and content in the context of science teaching and learning. In this study, science teachers also used IWBs as tools for students to explain questions and share their ideas. Students could transform the topic of "heat and temperature" to present their thoughts on the IWB. IWB technology improves teaching interactivity and student participation in science lessons (Smith et al., 2005). According to Geddis (1993), this transformation turns science teachers' subject-matter knowledge into teachable content knowledge. Science teachers might use IWB teaching methods to explain important concepts by designing some exercises for students with the concepts they have acquired.

On the other hand, IWBs helps science teachers who have difficulty implementing representational repertoires and instructional strategies in traditional classrooms. The science teachers in this study utilized IWB representations to transform the content to be taught into forms that are comprehensible to learners. They also let students use IWBs and observe explanations about the topic of "heat and temperature". This study showed scientific examples and teaching strategies, and interpreted the interaction of the technology, content and pedagogical elements of TPACK. This kind of description has been lacking in previous studies (Angeli & Valanides, 2009; Gillen et al., 2008). According to the transformative view (Angeli & Valanides, 2009; Gess-Newsome, 1999), TPACK is considered as a distinct set of knowledge constructed from other forms of teacher knowledge. In this study, science teachers developed their TPACK to transform IWB technology, pedagogy and content knowledge.

Furthermore, TPACK is not considered a distinct form of knowledge, but a body of knowledge, which is made up of other forms of teacher knowledge that are integrated during the act of teaching (Angeli & Valanides, 2009). In this study, science teachers integrated IWB resources such as e-books, story animation, and the Internet into teaching and learning. Story animation stimulates students' learning motivation. E-books help students control the themes better. The Internet provides abundant learning resources. This also answered the questions posed by some studies, showing that IWBs help to support planning and are thus important and highly motivating teaching resources (Gillen et al., 2008; Holmes, 2009; Warwick & Kershner, 2008). Peer coaching has performed well the functions of teachers' "learning community" (Brown & Campione, 1996), which aims to foster a community of learners, enrich the knowledge of a classroom community, and provide a place for science teachers to interact with more accomplished co-workers. Teachers in learning communities engage in complex, authentic tasks through distributing their expertise (Shulamn & Sherin, 2004).

6. Conclusion and recommendations

In conclusion, using IWB technology could help science teachers develop their TPACK, and peer coaching not only enhanced the development of the science teachers' TPACK, but also developed teaching skills for integrating technology into lesson designs and strategies. Therefore, a teaching model integrating two simultaneous interventions of IWB technology and peer coaching can offer an efficient way to facilitate the growth of science teachers' TPACK.

In this study, the researcher used a multimethod approach and qualitative in-depth study to develop an IWB-based model to examine the impact on the TPACK of secondary science teachers. In future studies, researchers may present quantitative data, which can overcome limitations of qualitative research when it comes to large samples and inference. When designing questionnaires, some researchers have focused on "technology" and developed the TPACK surveys (Graham et al., 2009; Koehler et al., 2007). On the other hand, the future study is expected to display learning results from the students in order to examine the TPACK development of science teachers. According to Tuan, Chang, Wang, and Treagust (2000), student perceptions of teachers' knowledge may provide rich information about students' cognition and classroom processes. It may provide a relatively objective (via surveying multiple students) account and alternative view that supplements traditional teacher self-reports. Another benefit of student-perceived instruments, from a pragmatic point of view, is that they make it easier to collect large samples for research.

In addition, this study assumed that an IWB is a technological media. This suggests that researchers can integrate diverse technology to better understand science teachers' TPACK development.

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