THE IMPLEMENTATION STUDY OF A TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE BASED INSTRUCTIONAL DESIGN MODEL

by

CHIA-JUNG LEE

(Under the Direction of ChanMin Kim and J. Michael Spector)

ABSTRACT

A Technological Pedagogical Content Knowledge (TPACK) based instructional design (ID) model is proposed to improve preservice teachers' technology application in multidisciplinary technology integration courses. A design-based research (DBR) approach was applied for this dissertation to develop, implement, evaluate, and revise three prototypes of the TPACK-based ID model to generate a robust model for preservice teachers' TPACK improvement. The development and implementation of the three prototypes comprises three implementation studies presented in this dissertation, each of which has been or will be submitted for publication in a refereed journal. The progression of the prototypes included constant revision of activities to improve preservice teachers' teaching-related knowledge and increase of practical opportunities for them to apply technology in consideration of subject matter. Results showed that preservice teachers' understanding and skills with regard to TPACK gradually improved as the prototypes progressively improved, and the third prototype implementation study demonstrated the most promising framework for preservice teachers' TPACK acquisition among the three prototypes.

INDEX WORDS: Technology integration, TPACK, Instructional design model, Preservice teacher education, Learning by design

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DEDICATION

I dedicate this dissertation to my family.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

This dissertation titled “The Implementation Study of a Technological Pedagogical Content Knowledge Based Instructional Design Model” presents the development and implementation of three prototypes of a Technological Pedagogical Content Knowledge (TPACK) based instructional design (ID) model that aims to improve preservice teachers’ technology integration by enhancing their TPACK. In the following sections, the background and purposes of the study, the research methodology, and the dissertation overview are presented.

Background of the Study

Especially since the mid-1970s with the rise of computer technologies, researchers have been interested in the potential of technology in education. Over the past decades, one of the most important issues in educational innovation has been the integration of technology in education (Hew & Brush, 2007; Shattuck, 2007). While more and more educational technologies have been set up in schools, researchers have been concerned about whether technologies are being effectively applied to support instruction and learning (Niess, 2005; Spector, 2011). Some teachers tend not to use computers for teaching even though they have adequate computers in the classroom (Becker, 2000; National Center for Education Statistics, 2009). In many educational circumstances, digital technology is an after-thought tool for teachers instead of a critical element integrated into students’ learning (Davis & Falba, 2002). Also, some teachers use technology superficially, such as preparing teaching materials or having students search for online information instead of working on inquiry-based activities (Kim, Hannafin, & Bryan, 2007). Many concerns have been raised about the preparedness aspect of technology integration in teacher training programs (Angeli, 2005; Ertmer, Conklin, Lewandowski, Osika, Selo, & Wignall, 2003; Wright & Wilson, 2006). According to a report by the National Center for Education Statistics (2009), only 25% of teachers felt well prepared to integrate technology into their teaching during their undergraduate teacher education programs.

Technology-focused courses that omit pedagogy and content-focus in teacher training programs can lead to ineffective use of technology in the classroom (Niess, 2005; Pope, Hare, & Howard, 2005). Some researchers have discussed the gap between what teachers are taught in teacher training programs and what they are expected to do in the classroom (Angeli & Valanides, 2005), arguing that teacher training programs should develop preservice teachers' integrated knowledge among the subject matter, technology, and pedagogy so as to help them apply technology effectively to support students' learning (Jimoyiannis, 2010; Niess, 2005, Niess et al., 2009; Polly, McGee, & Sullivan, 2010). As stated by Angeli (2005),

> Teacher educators… need to explicitly explain the pedagogical reasoning that guided the design of instruction with technology, so that student teachers can experience these new visions of learning with technology and examine how the teachers' role changes, how the subject matter gets transformed, and how the learning process is enhanced. (p. 395)

Technological Pedagogical Content Knowledge (TPCK, Mishra & Koehler, 2006, changed to TPACK, Thompson & Mishra, 2007) has been widely discussed since it provides a conceptual framework to guide preservice teachers in developing technological skills in consideration of students' learning and content characteristics. TPACK consists of seven knowledge domains—three basis knowledge domains (technological knowledge, pedagogical knowledge, and content knowledge) and four integrated knowledge domains (technological pedagogical knowledge, pedagogical content knowledge, technological content knowledge, and technological pedagogical content knowledge). In terms of TPACK, teachers' professional development of technology integration should go beyond the three basis knowledge domains and focus on the integrated knowledge domain—technological pedagogical content knowledge (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

There have been some studies that attempted to improve preservice teachers' TPACK by using instructional design (ID) models (Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010). An instructional design model provides guidelines to help designers organize instructional activities to maximize the effectiveness of instruction and facilitate learning (Andrews & Goodson, 1980; Branch, 2009; Gagné, Wager, Golas, & Keller, 2005; Gustafson & Branch, 2002). However, to our knowledge, ID models that have been proposed for TPACK improvement were developed for or implemented in subject-specific settings (e.g., the science classroom including preservice teachers with majors of biology, chemistry, physics, etc.). According to a report by the National Center for Education Statistics (2008), which investigated educational technology in teacher education programs for initial licensure among 1439 institutions, 51% of the institutions offered 3- or 4- credit stand-alone educational technology courses, and 34% of the institutions offered 1- or 2- credit stand-alone educational technology courses. This report revealed that a great number of educational technology courses have not been offered for specific subject areas, implying that integration courses take place in a multidisciplinary setting with preservice teachers with very little if any teaching experience or pedagogical knowledge. Thus, there is a need to provide practical and systematic guidelines in multidisciplinary technology integration courses for preservice teachers' TPACK improvement until such courses cease to exist (which is the case in France, for example).

Purpose of the Study

The purposes of this dissertation are: (a) to develop a TPACK-based ID model for multidisciplinary technology integration courses, (b) to implement the model and examine its effects on preservice teacher TPACK and associated skills, (c) to revise and refine the model based on implementation study findings, and (d) to generate practical and empirical knowledge of how the model works for preservice teachers' TPACK improvement. The ultimate goal of this dissertation is to help preservice teachers become better able to apply technology effectively in their future teaching in order to highly engage their students in learning and improve their learning results.

Methodology

This dissertation is presented in a manuscript format, which means writing "the dissertation as an article (or series or set of such articles) ready for publication, [and preparing] appendices for any additional information the committee may desire for pedagogical and examination purposes" (Krathwohl, 1994, p. 31). This writing format is conductive to disseminating and publishing research findings and also provides effective training for doctoral students' future academic writing (Duke & Beck, 1999). This dissertation is the compilation of three articles submitted or planned for submission to refereed journals:

1. Chapter 2: An implementation study of a TPACK-based instructional design model in a technology integration course;
2. Chapter 3: The second prototype of the development of a TPACK-based instructional design model: an implementation study in a technology integration course;

3. Chapter 4: The third prototype of the development of a TPACK-based instructional design model: an implementation study in a technology integration course.

The three articles are tightly connected to each other because the three studies reported in the three articles were conducted using the design-based research approach (DBR). Chapters 2, 3, and 4 present the three implementation studies of the three prototypes (Prototypes I, II, and III) of the TPACK-based ID model, respectively. Figure 1.1 illustrates the stages of applying DBR that shows the gradual and systematical development and refinement of the model.

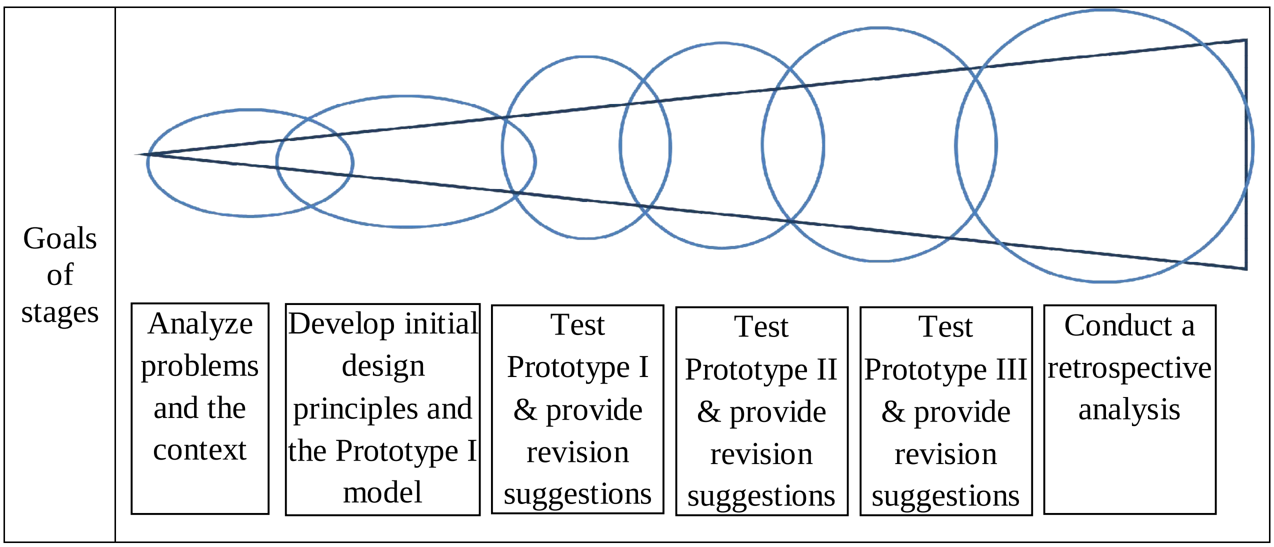

Figure 1.1. DBR as the methodology of research

DBR is a promising methodology for educational research since it generates feasible and practical knowledge and solutions for teachers, instructors, practitioners, etc. (Reeves, 2006). DBR possesses the following characteristics (Cobb, diSessa, Lehrer, & Schauble, 2003; Collins, Joseph, & Bielaczyc, 2004; DBR Collective, 2003):

1. DBR bridges theory and practice: DBR enables researchers to design and test interventions in real world situations, in which the interventions embody specific

theoretical concepts and "reflect a commitment to understanding the relationships among theory, designed artifacts, and practice" (DBR Collective, 2003, p. 6).

2. DBR evaluates interventions formatively: DBR focuses on the iterative process of testing and revising an intervention so as to optimize its effects. As described by Collins et al. (2004), the application of DBR is the process of putting "a first version of a design into the world to see how it works. Then, the design is constantly revised based on experience…" (p. 18).

DBR is considered proper for this dissertation for the following two reasons: (1) the TPACK-based ID model is a designed artifact that attempts to uncover as well as establish the relationships between the TPACK theory and practice in teacher training programs and (2) the TPACK-based ID model requires progressive refinement by conducting continual testing in real environments so as to increase its effects on improving preservice teachers' TPACK. Table 1.1 lists the tasks and timeline of DBR in developing and improving a TPACK-based ID model. Figure 1.2 shows the structure of this dissertation.

Table 1.1

Phases of Applying DBR to This Research

Phase	Phase 1 Preliminary research		Phase 2 Prototyping	Phase 3 & 4 Summative evaluation & reflection
Goals	problem analysis	initial design and development	testing Prototypes I, II, & III	retrospective analysis
Tasks	• reviewing literature • analyzing context(s) • developing theoretical framework	• formulating initial design principles • developing the initial prototype of the TPACK-based ID model	• designing, developing, implementing, & evaluating the prototypes • revising the design principles based on the findings of each prototype	• reflecting on and deriving effective design principles • providing recommendations for future research and development
Timeline	2009-2010	2010-2011	Prototype I: Aug, 2011-Jan, 2012 Prototype II: Jan-Aug, 2012 Prototype III: Aug-Dec, 2012	Dec, 2012-Feb-May, 2013

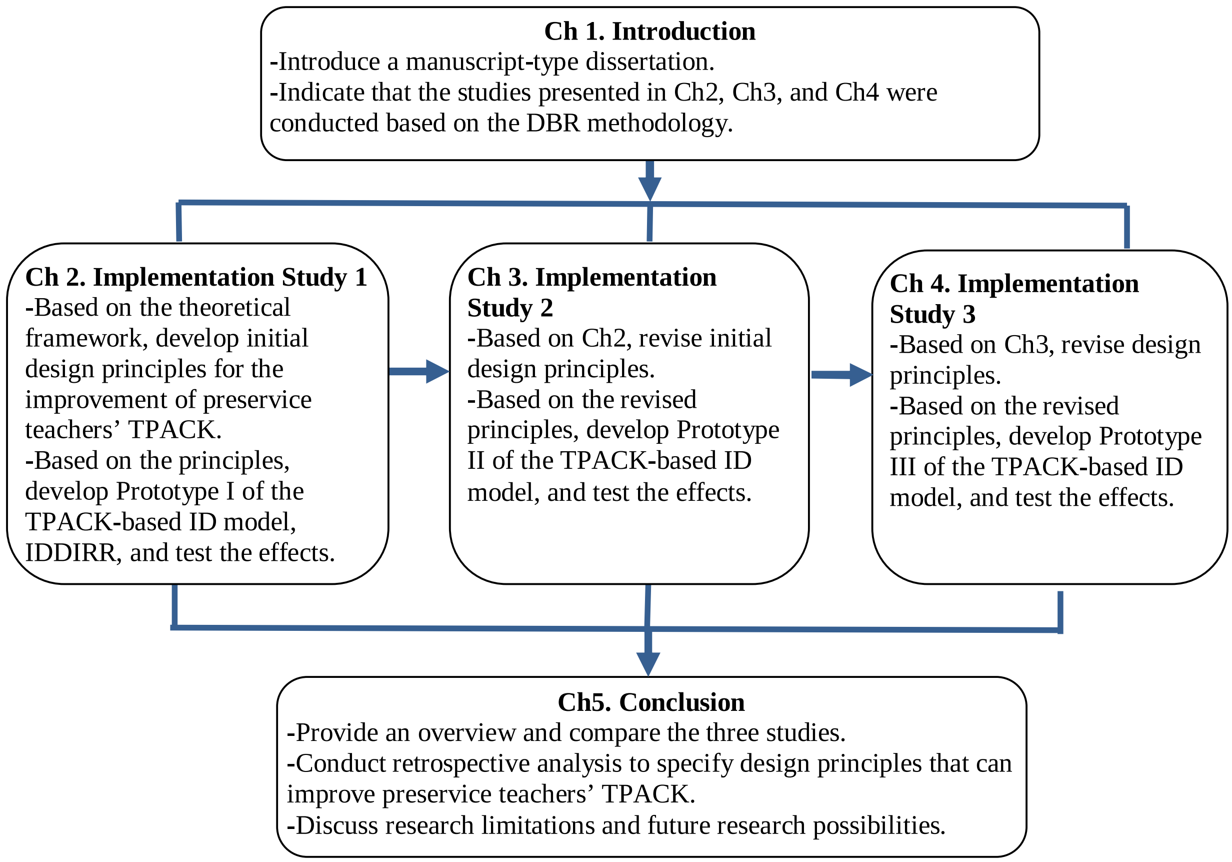

Figure 1.2. Dissertation structure

Research Questions

In terms of research purposes, three research questions guided this dissertation:

1. What are the effects (of the Prototype I, II, or III) of the TPACK-based ID model on preservice teachers' TPACK?
2. How does the implementation study (of the Prototype I, II, or III) of the TPACK-based ID model inform the re-design of the model?
3. What are the characteristics of a practical and effective TPACK-based ID model that can improve preservice teachers' TPACK in a multidisciplinary technology integration course?

Research Questions 1 and 2 were investigated iteratively in the implementation studies of the three prototypes of the TPACK-based ID model as presented in Chapters 2, 3, and 4. Research Question 3 is a question that requires a comprehensive analysis of implementation findings from the three prototypes and is discussed in Chapter 5.

Dissertation Overview

This dissertation starts with this introduction (Chapter 1) that states existing problems regarding technology integration in education and argues for the need to develop an ID model for preservice teachers' TPACK acquisition. This chapter also discusses the application of the DBR approach and informs the three consecutive implementation studies presented in Chapters 2, 3, and 4, respectively. Chapter 2, "An implementation study of a TPACK-based instructional design model in a technology integration course", reports the preparation for (e.g., literature review, problem analysis, forming initial design principles, etc.) and development of Prototype I of the TPACK-based ID model (i.e., TPACK-IDDIRR) as well as an implementation study in which the model was applied. Prototype I was built on the assumption that the mastery of separate domains of TPACK (e.g., TK, PK, and CK) was critical in understanding the complex interplay of TPACK. Consistent with this assumption, the implementation findings of Prototype I reported that preservice teachers' lack of pedagogical knowledge interfered with their TPACK development. These findings provided suggestions for revision and led to Prototype II. Chapter 3, "The second prototype of the development of a TPACK-based instructional design model: an implementation study in a technology integration course", reports on the revision of the initial design principles, the development of Prototype II of the TPACK-based ID model, and the implementation of Prototype II. Next, Chapter 4, "The third prototype of the development of a TPACK-based instructional design model: an implementation study in a technology integration course", reports on the revision of design principles based on the suggestions from Chapter 3, the development of Prototype III of the TPACK-based ID model, and the implementation of Prototype III.

A critical challenge with developing the prototypes was to balance between the development of a multidisciplinary approach to acquiring TPACK and the notion that TPACK is the integration with *specific* content knowledge. To overcome the challenge, the progressive prototypes took the content issue into consideration by gradually enhancing practical opportunities for preservice teachers to develop artifacts (e.g., lesson plans) around specific content areas based on their specializations or interests. However, it should be acknowledged that the researcher (also the instructor in this research) was more in a position to support preservice teachers' technology integration than to judge the quality of their lesson plans. To ensure the accuracy of the content reflected in the lesson plans, the final prototype of the model suggests that future research should have preservice teachers to collaborate with content experts to validate the content.

Finally, in Chapter 5, a comprehensive and retrospective overview of the three implementation studies is conducted. The chapter compares the three prototypes on design principles, relevant models, research methodologies, and findings. Then, the characteristics of a valid TPACK-based ID model, evolving from the iterative evaluation of the three prototypes, that can enhance preservice teachers' TPACK are specified. Also, limitations of the dissertation, future research possibilities, and implications are discussed.

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CHAPTER 2

AN IMPLEMENTATION STUDY OF A TPACK-BASED INSTRUCTIONAL DESIGN MODEL IN A TECHNOLOGY INTEGRATION COURSE[1]

[1] Lee, C. J. & Kim, C. A version of this chapter was submitted to *Educational Technology Research and Development.*

Abstract

The purpose of this study was to develop an instructional design model for preservice teachers' learning of technological pedagogical content knowledge (TPACK) in multidisciplinary technology integration courses and to apply the model to investigate its effects when used in an actual setting. The model was applied in a technology integration course with 15 participants from diverse subject majors. Data included groups' lesson plans, students' written materials, instructor's field notes, and TPACK surveys. The results revealed the following: (1) The participants had difficulties understanding pedagogical knowledge (PK), which hindered their learning of integrated knowledge of TPACK; (2) the participants' integrated knowledge were not clearly established; and (3) the participants' learning of TPACK was the combination rather than the integration of PK, technological knowledge (TK), and content knowledge (CK). Suggestions and implications for refinement of the model and future research possibilities are discussed.

Keywords: technology integration; TPACK; instructional design model; preservice teacher education; learning by design

An Implementation Study of a TPACK-Based Instructional Design Model in a Technology Integration Course

Many argue that the use of technology is a promising way to enhance effective teaching and learning (Sandholtz, Ringstaff, & Dwyer, 1997; Voogt, Tilya, & van den Akker, 2009; Williams, Linn, Ammon, & Gearhart, 2004). Educational associations have acknowledged the importance of technology and set forth standards for the use of technology to enhance teaching and learning (e.g., International Society for Technology in Education, 2008; National Science Teachers Association, 2003; The International Board of Standards for Training, Performance and Instruction, 2006). However, studies show that technology equipped classrooms do not always lead to effective applications of technology (Kim, Kim, Lee, Spector, & DeMeester, 2013; Polly, Mims, Shepherd, & Inan, 2010). For instance, many teachers use interactive whiteboards to project the content of a lesson without interacting with students (Hall, 2010). Even though technology is used in teaching, some teachers tend to have students use technology for low-level searches instead of for inquiry-based learning activities (Kim, Hannafin, & Bryan, 2007). And those who prefer traditional teaching methods oftentimes consider technology an add-on instrument rather than a critical element integrating with teaching activities (Davis & Falba, 2002; Jimoyiannis, 2010).

The limited use of technology for teaching (e.g., just a presentation tool or a classroom management tool) rather than effective technology integration for *learning* (e.g., a facilitative tool for students' inquiry-based learning) has been attributed to numerous factors such as the inadequate pedagogical beliefs of teachers (Ertmer, 2005), their lack of motivation and volition (Kim & Keller, 2011), teacher efficacy (Tschannen-Moran, & Hoy, 2001), and so forth. Recently, the attribution goes back to the focus on teacher knowledge. This time, researchers are considering not just technological knowledge but integrative knowledge, which is necessary for effective technology integration. In recent years, it has been critically noted that the lack of teachers' extensive subject knowledge, content-supported pedagogical knowledge, and knowledge of technology integration leads to poor use of technology in education (Kim, Hannafin, & Bryan, 2007; Polly, McGee, & Sullivan, 2010). It has also been acknowledged that teacher training programs should provide teachers with the opportunity to develop *integrated* knowledge of the subject matter, technology, and pedagogy (Niess, 2005; Polly, McGee, & Sullivan, 2010).

Along this line, there has been an attempt to provide a theoretical foundation that highlights the need for the integrated development of teacher knowledge for technology integration—TPCK (Technological Pedagogical Content Knowledge, Mishra & Koehler, 2006). The TPACK framework (changed for pronouncing purposes, Thompson & Mishra, 2007) is designed to facilitate teachers' understanding about how to use technology to support student-centered learning and to transform the learning content into an easy-to-understand format. Within the framework, teachers' professional development of technology integration should go beyond just technology; the *integration* of technology, pedagogy, and content is emphasized (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

To help teachers acquire TPACK, Koehler and Mishra (2005) conducted studies in which the participants (faculty members, master students, and practicing K-12 teachers) were required to design technology-infused products for specific educational purposes. They investigated the design and the collaboration process in small groups and suggested that a design approach can help teachers learn TPACK:

> The *Learning by Design* approach requires teachers to navigate the necessarily complex interplay between tools, artifacts, individuals and contexts. This allows teachers to explore the ill-structured domain of educational technology and develop flexible ways of thinking about technology, design and learning and, thus, develop Technological Pedagogical Content Knowledge. (p. 25)

There have been studies that draw on a design-based approach to improve preservice teachers' TPACK or technology integration in specific subject area (Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010; Jimoyiannis, 2010). However, according to the National Center for Education Statistics (2008), around 51% of teacher education programs offered three- or four-credit stand-alone[2] educational technology courses to student teachers. In other words, a large percentage of teacher training programs do not offer technology courses based on subject areas. There is a need to provide explicit guidelines of utilizing the *Learning by Design* approach to instructors of *multidisciplinary* technology integration courses in which preservcie teachers have diverse subject majors so as to improve their TPACK.

An instructional design (ID) model building on the TPACK framework and integrating the *Learning by Design* approach can be useful in promoting preservice teachers' TPACK. An ID model would amplify the effectiveness of the *Learning by Design* approach and promote TPACK learning because it can offer explicit and systematic directions for instructors (Gustafson & Branch, 2002). Thus, the current study was conducted to (a) develop a TPACK-based ID model for preservice teachers' TPACK learning in a multidisciplinary technology integration course, (b) apply the model in an associated course to investigate its effects, and (c) plan for improvements in the model. To do so, the following research questions guided the study:

[2] The concept of stand-alone courses is compared to methods or content courses and field experiences of teacher candidates.

1. What are the effects of the initial TPACK-based ID model on preservice teachers' TPACK (technological pedagogical content knowledge)?
2. How do the results of the initial TPACK-based ID model inform future designers or researchers of design principles for the revision of the model?

In the following sections, first, we introduce the components of the theoretical foundation of this study, namely TPACK, the *Learning by Design* approach, and the ID models. Based on the framework, a TPACK-based ID model (called TPACK-IDDIRR) was developed. Second, we report on a study that implemented the IDDIRR model. Finally, suggestions and implications for future research based on the findings of this study are discussed.

Developing a TPACK-Based ID Model for Multidisciplinary Technology Integration Courses

The Theoretical Foundation

TPACK. TPACK is the framework comprised by the interplay of three knowledge bases: content, pedagogical, and technological knowledge (Mishra & Koehler, 2006). According to the interplay of knowledge, seven types of knowledge are included: content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). When teachers possess TPACK, they understand how to apply suitable technologies to teach specific content with appropriate pedagogy (Mishra & Koehler, 2006).

The *Learning by Design* Approach. Design is a process of solving problems (Silber, 2007) that are complex and ill-structured (Jonassen, 2008). Such problems include a series of cognitive tasks that require designers to identify and analyze problems, explore and evaluate solutions, and make decisions (Jonassen, 2008; The UK Technology Education Centre, n.d.). The *Learning by Design* approach encourages teachers to take the role of designers of learning activities (Kalantzis & Cope, 2005; Yoon, Ho, & Hedberg, 2006). The *Learning by Design* approach has been widely discussed for the integration of digital technologies into the classroom (e.g., Kalantzis and Cope, 2005), which has the potential to extend teachers' pedagogical repertoires by allowing them to design digital artifacts based on students' needs (Güler & Altun, 2010; Hjalmarson & Diefes-Dux, 2008; Koehler & Mishra, 2005). During the design process, participating teachers are engaged in an authentic environment to experience the complexity of learning and teaching contexts. For example, Koehler and Mishra (2005) applied the *Learning by Design* approach to enhance TPACK among faculty members (professors) and their graduate students with education backgrounds. In the study, faculty members and students worked collaboratively to design online courses in which they had to consider the complexity of integrating technology, pedagogy, and content.

The *Learning by Design* approach also facilitates learning through collaboration in which learner-centered activities are supported. In Jimoyiannis's (2010) study, inservice teachers worked in small groups to design a technology-integrated lesson plan. Interactions between inservice teachers and their trainers as well as collaborations among inservice teachers were emphasized. The design of the lesson plan relied mainly on the collaboration of the teachers and the discussion between the teachers and trainers.

Based on the review of the studies on the *Learning by Design* approach, the advantages of using the approach are summarized as follows (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Güler & Altun, 2010; Hjalmarson & Diefes-Dux, 2008; Jimoyiannis, 2010; Kalantzis & Cope, 2005; Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007): (a) It responds to the call of educational innovation concerning new approaches for students to learn in a digital environment; (b) it improves teachers' professional development by allowing them to create artifacts for students' learning needs; (c) it creates an authentic learning environment for teachers to experience the complexity of learning and teaching; and (d) it encourages collaborative work between researchers and teachers or among teachers.

ID Models for Technology Integration. While instructional design (ID) is a set of systematic procedures to provide instructional programs, an ID model describes how to practice these procedures. Based on our search in educational database (e.g., EBSCO, ERIC, etc.), studies that applied an ID model to improve preservice teachers' technology integration were mainly in science subject (e.g., Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010). Thus, we analyzed these studies to synthesize critical elements from each model for teaching technology integration and also drew on characteristics of traditional ID models to develop our model. In this section, first, we reviewed the three ID models that endeavored to support preservice science teachers' technology integration—Angeli's (2005) ID model, Angeli and Valanides' (2005) ID model, and Jang and Chen's (2010) TPACK-COPR model. Second, we synthesized the characteristics of the three models and also revised elements of the three models in order to meet the needs of a multidisciplinary technology integration course. Table 2.1 summarizes the comparison of the three ID models in terms of theoretical framework, elements, and features. The similarities and the adjustments for the development of our model were also specified.

Table 2.1

A Comparison of ID Models for *Enhancing Classroom Technology Integration*

Model	**Angeli ISD Model (2005)**	**Angeli & Valanides' ISD model (2005)**	**Jang & Chen TPACK-COPR Model (2010)**
Theoretical Framework	Instructional Design (ID) PCK	Instructional Design (ID) PCK	TPACK Peer coaching
Elements	Identify topics	Identify a topic (with consideration of school contexts, previous classroom experiences, and personal beliefs)	TPACK comprehension (TPACK-C)
	Select topics	Transform the content (in conjunction with learners' backgrounds, pedagogy, and technology)	Observation of Instruction (TPACK-O)
	Transform content	Implement a lesson plan and assess students' learning outcomes	Practice of Instruction (TPACK-P)
	Select appropriate technological tools	Reflect on personal teaching performance for the revision of the lesson plan	Reflection of TPACK (TPACK-R)
	Tailor representations to students' characteristics		
	Integrate technology in teaching		
	Assess students' performance		
	Reflect		
	Revise		
Feature (s)	. Specific stages for the instruction of technology integration . Instructors demonstrate the use of technology and explain its pedagogical potentials.	The consideration of teacher beliefs, prior experiences, and contextual factors	Comprehend the TPACK concept first so as to build a knowledge base of technology integration

Similarities	1. Present systematic instructional procedures; 2. Demonstrate technology-integrated examples; 3. Integrate design-based learning activities; 4. Build on state-of-the-art theories of instructional technology.		
Adjustments	Add a stage introducing TPACK—as the first stage	Focus on the last two elements of practical and design activities more than on the first two elements of beliefs and contextual factors.	Add a stage of revision after the stage of reflection.
	Provide more opportunities for preservice teachers to experience the process of design, implementation, reflection, and revision.		

Angeli's (2005) ID model and Angeli and Valanides' (2005) ID model were both developed based on the frameworks of an ID model and PCK (Shulman, 1987) but have different foci. Angeli's ID (2005) model specifies clear stages for applying technology in teaching, whereas Angeli and Valanides' (2005) ID model is like conceptual guidance that focuses on theoretical principles instead of practical stages. Specifically, Angeli's (2005) ID model was built on the expanded view of PCK— teachers' understanding of pedagogy should include technology so as to provide digital support for transforming content. According to expanded PCK, Angeli presented a nine-stage ID model that guides preservice teachers in developing technology-integrated lesson plans (see Table 2.1). Before the implementation of the model, she specifically suggested that instructors model the use of technology and explain its pedagogical potentials about how the technology represents particular learning content. In contrast, Angeli and Valanides' (2005) ID model includes only four instructional principles in order to include both personal and context factors that can cause impacts on technology integration (see Table 2.1). Angeli's (2005) ID model depicts explicit instructional stages, and Angeli and Valanides' (2005) ID model addresses conceptual elements that ID designers should consider when supporting teachers' technology integration.

These two models were applied in science methods courses, which means that the two models are particularly suitable for science-oriented contexts. Since the determination of technology and pedagogy is affected by the subject area (Mishra & Koehler, 2006), elements of the two ID models should be modified so as to have overarching features for a multidisciplinary course. Two adjustments were made so as to develop a new ID model in the current study. First, a stage, such as *introducing TPACK*, should be set as the first stage in the new model. This is because preservice teachers in this context may not have the knowledge base (TK, PK, or CK) to identify and select suitable topics for technology integration. Second, the new model should put more emphasis on helping preservice teachers *develop, implement,* and *revise* educational technological products (the 3rd and 4th principles of Angeli and Valanides' (2005) model), than on asking them to consider school contexts, previous classroom experiences, personal beliefs, and learners' backgrounds (the 1st and 2nd principles).That is because preservice teachers may not have prior teaching experience. It can be difficult for them to consider how such contextual factors affect their teaching.

The third ID model reviewed is Jang and Chen's (2010) TPACK-COPR model highlighting four elements: *C*omprehension of TPACK; *O*bservation of instruction, *P*ractice of TPACK, and *R*eflection of TPACK. The first element, comprehension, was especially emphasized to provide a theoretical foundation to teachers before they engage in the practical activities in the later stages. In Jang and Chen's (2010) study, however, the learning process ended at the stage of reflection, in which preservice teachers reflected on their teaching performance in the stage of practice. They were not explicitly required to revise their lesson plans after the stage of practice. For the development of a new model for this study, we added a stage of revision after the stage of reflection because the revision process can promote the refinement of a lesson plan or a digital design, facilitate another cycle of design-based activities (Fernández, 2005, 2010), and help preservice teachers transfer their reflections into the revising activity so as to deepen their understanding of TPACK. .

We also found that a crucial element of the ID model— the "iterative" characteristic— was not emphasized enough in these three models. Although all three models include the iterative feature, participants in the implementation studies went through the process of the model only once. Preservice teachers should be given chances to go through the stages of design, implementation, reflection, and revision more than once so as to enhance the learning of TPACK (Jimoyiannis, 2010; Kalantzis & Cope, 2005; Koehler & Mishra, 2005). Some generic guidelines emerged based on the comparison in Table 2.1 that can serve as initial design principles for developing the model:

(1) Explicit and systematic procedures: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK;

(2) TPACK introduction and demonstration stages: Introducing the TPACK theory can build preservice teachers' knowledge base of technology integration, and demonstrating technology-integrated examples can prepare them for designing technological teaching artifacts.

(3) Design-based learning activities: Creating a lesson plan and a corresponding digital artifact can prompt preservice teachers to analyze the subject content and learning needs of students.

(4) A cyclic design-based learning process: Opportunities for preservice teachers to go through the design process—implementation, reflection, and revision of a lesson plan and a corresponding digital artifact—can enhance the learning of TPACK.

The TPACK-IDDIRR Model

Based on the four design principles discussed above, we developed the TPACK-IDDIRR (*I*ntroduce, *D*emonstrate, *D*evelop, *I*mplement, *R*eflect, and *R*evise) model as shown in Figure 2.1. IDDIRR transforms the principles into practical procedures. In this study, the four design principles were considered a conceptual framework, and the IDDIRR model served as a practical framework that embodies these principles.

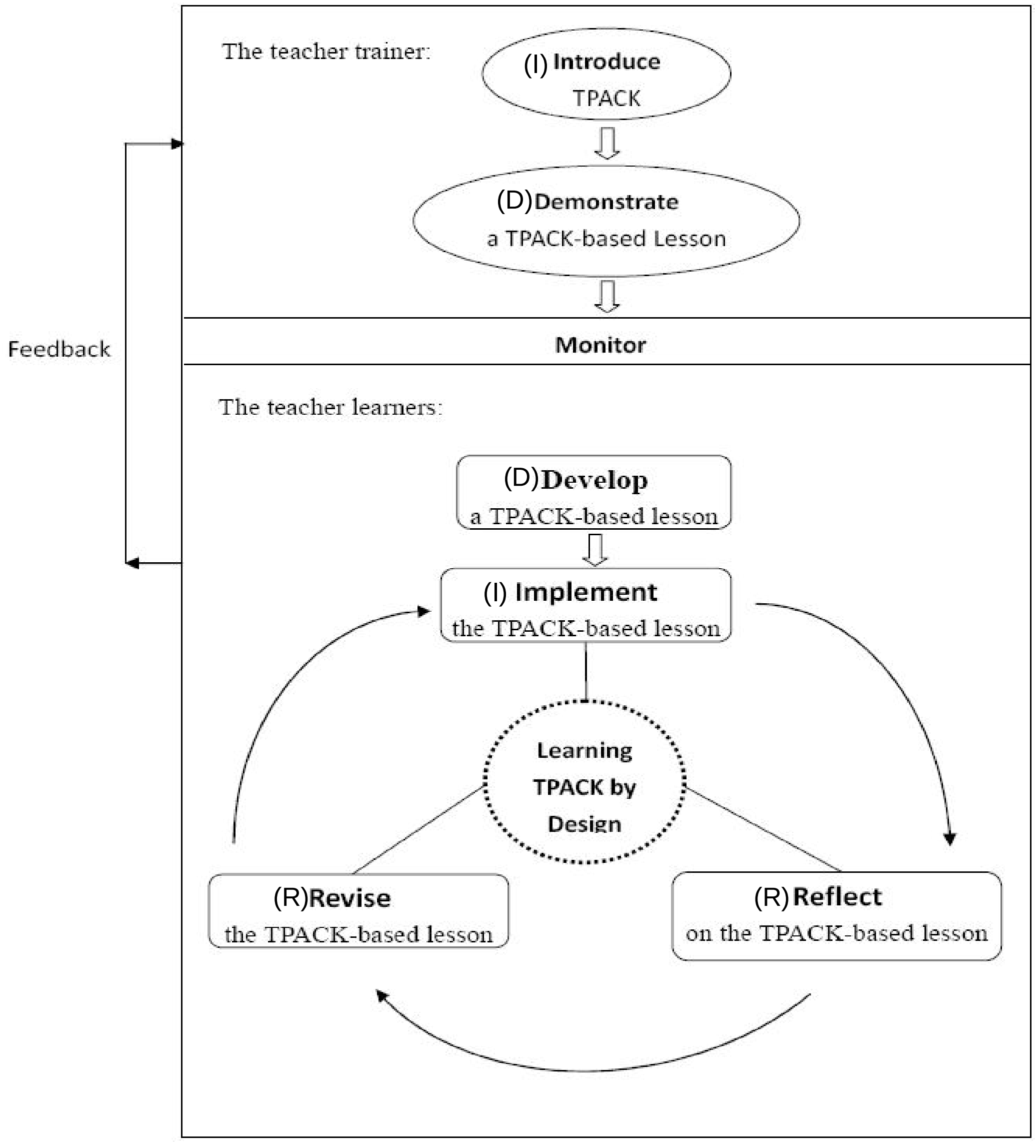

Figure2.1. The TPACK-IDDIRR Model

Applying the TPACK-IDDIRR model in a technology integration course, the instructor starts at the *introduce* (I) stage to help preservice teachers understand TPACK (Jang & Chen, 2010). The purpose of the first stage is to build preservice teachers' knowledge base of TPACK in order to facilitate the learning in the design activities later on. The instructor explains the meaning of the seven domains of TPACK and provides examples for each domain. However, this step focuses mainly on familiarizing preservice teachers with CK, PK, and TK because the mastery of these three domains can serve as the basis for integrated understanding of TPACK[3]. Second, the instructor *demonstrates* (D) a TPACK-based teaching example to preservice teachers. Preservice teachers are expected to enhance their understanding of TPACK by observing the demonstrated teaching example (Bandura, 1977; Jang & Chen, 2010; Merrill, 2007).

Before the third stage, the instructor should monitor and scaffold the following stages that will be carried out mainly by preservice teachers. The following stages (*Develop*, *Implement*, *Reflect*, and *Revise*) are iterative learning activities that comprise *Learning TPACK by Design* as shown in Figure 2.1 (Angeli, 2005; Angeli & Valanides, 2005; Fernández, 205, 2010; Jimoyiannis, 2010). During the third stage, preservice teachers are divided into small groups and each group *develops* (D) a TPACK-based lesson plan according to what they learned in the previous two stages. They are expected to confront multi-faceted difficulties with identifying suitable subject topics, selecting technological tools accompanied with pedagogical methods, and forecasting possible problems. Since TPACK refers to the knowledge possessed by the preservcie teachers that is difficult to empirically identify or observe, artifacts or activities to which TPACK is applied are often assessed (e.g., Brantley-Dias, Davis, Richardson, Ball, & Sarsar, 2013). Thus, the TPACK-IDDIRR model includes that the instructor and researchers evaluate lesson plans developed by preservice teachers to assess their TPACK acquisition. Fourth, the first member from each group *implements* (I) the lesson plan, as the process is

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[3] The assumption of this study was that preservice teachers should well understand the meaning of the three core domains (TK, PK, and CK) and then they can relate the understanding to integrative knowledge—the integrated domains of TPACK (e.g., PCK, TPK, TCK, and TPACK).

videotaped. Other preservice teachers act as students and provide feedback to the first member of each group who teaches the lesson. Next, after reviewing the videotape, each group *reflects* (R) on the lesson plan and discusses the pros and cons of the plan. Finally, each group *revises* (R) the lesson plan according to their collective reflection. Then, the second member from each group *implements* (I) the revised lesson plan and each group goes through the *reflect* (R) and *revise* (R) stages again. The IRR stages work iteratively until all the members of each group have a chance to implement the lesson plan (Fernández, 2005, 2010).

The systematic stages of IDDIRR respond to the first design principle that provides practical solutions to the learning of TPACK. The *Introduce* and *Demonstrate* stages of the model respond to the second design principle that helps preservice teachers understand the TPACK concept. The elements of the *Learning TPACK by Design* activities—*Develop*, *Implement*, *Reflect*, and *Revise*—are design-based and should be carried out iteratively, which respond to the third and the fourth design principles respectively.

Implementation Study

Methodology

The purposes of this study were not only to develop a TPACK-based ID model but also to apply the model and investigate how the model improves preservice teachers' TPACK. A case study approach was chosen for this study, because "case study is an in-depth exploration from multiple perspectives of the complexity and uniqueness of a particular project, policy, institution, programme or system in a 'real life' context" (Simons, 2009, p. 21). Since this study attempted to generate an in-depth understanding of the model when it is implemented in the required context, a case study was considered an appropriate methodology.

Context and Participants

This IDDIRR model was applied in a technology integration course in a southeastern university in which students had diverse majors. Since one of the researchers was also the instructor of the class, the setting allowed direct access and long-term investigation. This context satisfied Spradley's (1980) recommended criteria for choice of settings: simplicity, accessibility, unobtrusiveness, permissibleness, and frequently recurring activities. The course was modified to include IDDIRR stages for the teaching of TPACK in the fall semester of 2011. The course lasted 15 weeks and ran for 3 hours per week. Twenty students enrolled in the class, while 15 of them participated in the study voluntarily (10 of which were females). The participants' ages ranged from 19 to 21.

The title of the course suggests that the course was mainly open to preservice teachers; however, students in other programs were also allowed to enroll. During the semester the research was conducted, only three participants had taken education-related courses previously, and none of them had a practicum experience in a preK-12 classroom. Majors of the participants included: child and family development, communication science and disorders, pre nursing, and recreation and leisure studies.

Technological tools taught in the course included (a) communication and collaboration tools (Google Docs, in2Books, podcasting tools, the Globe Program, Blogging tools, etc.); (b) graphic software (floorplanner); (c) a social bookmarking tool (e.g., Delicious); (d) video making tools; (e) concept-mapping tools (Inspiration & Kidspiration); (f) Web 2.0 tools (Google Site, WebQuest, etc.); and (g) presentation tools (PowerPoint games). Class students were informed that they would not only learn technology but also learn how to use technologies in teaching activities.

Data Collection

Data collected in this research included: (1) the mid- and post- TPACK, (2) students' written materials, (3) groups' lesson plans and corresponding digital products, and (4) the instructor's field observation notes. The five stages of IDDIRR were divided into two big parts to collect data—*Introduce* and *Demonstrate* TPACK and the *Learning TPACK by Design* activities.

The TPACK survey was modified based on the four TPACK-related surveys: (1) Survey of Pre-service Teachers' Knowledge of Teaching and Technology (Schmidt, Baran, Thompson, Koehler, Shin, & Mishra, 2009); (2) Survey of Technological Pedagogical and Content Knowledge (Sahin, 2011); (3) Assessing Students' Perceptions of College Teachers' PCK (Jang, Guan, & Hsieh, 2009); and (4) TPACK in Science Survey Questions (Graham, Burgoyne, Cantrell, Smith, Clair, & Harris, 2009). Schmidt et al.'s survey served as a foundational structure for the survey of this study, but items from the other three surveys were adopted in order to supplement items for the seven TPACK domains. For example, in Schmidt et al.'s survey, there is only one item for each subject area (mathematics, literacy, science, and social studies) in the PCK domain. We adopted PCK-related items in the Sahin and Jang et al. surveys to supplement items in the PCK domain (e.g., "I have knowledge in making connections between my content area and other related courses" (Sahin), and "I can use a variety of teaching approaches to transform content into comprehensible knowledge" (Jang et al.). Similarly, some items of Graham et al.'s survey were adopted to supplement items in the TCK domain.

The modified TPACK survey contained 55 items measuring 7 knowledge domains of TPACK: 16 TK items, 8 CK items, 9 PK items, 7 PCK items, 6 TCK items, 5 TPK items, and 4 TPACK items. The participants responded to each item using a 5-point Likert scale from (1) "strongly disagree" to (5) "strongly agree". In this study, the Cronbach's alpha values on the various sub-scales ranged from .55 to .91 for the mid-test results and from .73 to .89 for the post-test results. The Cronbach's alpha value of the 55 items was .94 for the mid-test results, while it was .93 for the post-test results. Table 2.2 presents the Cronbach's alpha values of all the domains of TPACK.

Table 2.2

Reliabilities of the Survey

Domains of TPACK	Mid-test Cronbach ∝	Post-test Cronbach ∝
TK	.86	.74
CK	.73	.79
PK	.88	.89
PCK	.81	.73
TCK	.79	.75
TPK	.55	.83
TPACK	.91	.88
Total	.94	.93

* 16 items of TK, 8 items of CK, 9 items of PK, 7 items of PCK, 6 items of TCK, 5 items of TPK, and 4 items of TPACK

Procedures

Introduce and Demonstrate TPACK. Data collected during these stages were the instructor's field notes, students' written materials, and the mid-TPACK survey. The introduction of TPACK began in Week 2 after the participants were given an introduction of this course during Week 1. The instructor used videos and PowerPoint presentations to introduce (*I-Introduce*) TPACK. As described in the TPACK-IDDIRR model section earlier, the focus of *Introduction* was on the three core domains of TPACK—TK, CK, and PK. The participants were given the definitions of TK, CK[4], and PK[5] to learn the concepts. For example, the definition of

4 The definition of CK given to participants: A teacher that possesses CK has a deep understanding of the knowledge in her/his subject and knows the content standards of the subject. An example of CK given to participants: The knowledge of a period of the history such as the Civil War.

TK refers to that “A teacher that possesses TK can use a variety of educational technologies in teaching”. Then, the participants were given examples of TK. For instance, “A teacher uses PowerPoint, Excel, smart board, etc. in teaching”. Note that the provided examples were simple and basic, not meeting the expectation such as using technology to support higher-order learning skills, because the purpose of this beginning step was to help preservice teachers grasp the concepts and have confidence to learn TPACK more.

In Week 7, the instructor demonstrated (*D-Demonstrate*) a TPACK-integrated teaching example to instruct integrated knowledge of TPACK (e.g., TPK, TCK, and TPACK). The example was demonstrated after the participants learned Microsoft Photo Story—a free tool for creating slideshows. The instructor demonstrated a lesson “the American Civil War” using two technological tools—Microsoft Photo Story to tell the story about the American Civil War and Wikipedia to show the relevant history. Then, the participants were asked to compare the two technological tools based on how the tools represented the content (TCK) and to evaluate which one could better help students learn the content (TPK & TPACK). After the TPACK *Introduce* and *Demonstrate* stages, a mid-TPACK survey was conducted to understand the effects of applying the two stages to teaching TPACK to participants.

***Learning TPACK by Design* Activities: Develop (D), Implement (I), Reflect (R) on, and Revise (R) a TPACK-based Lesson Plan.** To facilitate the participants’ TPACK discussion when they engaged in the *Learning TPACK by Design* activities with group members, as well as to facilitate data collection, an online learning environment in Google Docs was created to allow the participants to develop, discuss, reflect on, and revise their lesson plans. Every group then submitted the created lesson plan and associated digital products to their Google Site pages.

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5 The definition of PK provided to participants: A teacher that possesses PK has the understanding of students’ learning needs or difficulties. An example of PK: Group discussion.

During these activities, the instructor continued to record observations and reflections on the participants' learning. The participants' written materials regarding TPACK were also collected. Finally, post-TPACK surveys were conducted when these activities were completed.

Based on the model, four activities in *Learning TPACK by Design* were carried out: every group developed (D) a TPACK-based lesson plan; every group implemented (I) its lesson plan in the class; members of every group discussed the implementation and reflected on (R) the lesson plan; and every group revised (R) the lesson plan accordingly. The participants themselves created four groups with five people each. Since the participants had different majors, every group discussed a subject/topic that they were able to integrate best with technology. Topics decided by the four groups were: days of the week, holidays, and months of the year; living and non-living things; cells; and multiplication for five, nine, and ten.

Members from Group 1 and Group 2 developed (D) the groups' lesson plans in Week 7 and went through the IRR stages during Week 7 to Week 9, and members from Group 3 and Group 4 developed (D) the groups' lesson plans in Week 11 and went through the IRR stages during Week 12 to Week 15. The TPACK-based lesson plan developed by each group was 25-30 minute long and was divided into three approximately 10-minute sections for the implementation (I) purpose. Each member of every group was required to teach one section in the class. Thus, some sections were taught independently, while some were taught in pairs. The teaching process was videotaped for all the groups. After the teaching of the first section of the lesson plan, members of every group watched the teaching video, reviewed feedback provided by the peers, and reflected (R) on the lesson plan. Then, every group discussed ways to revise (R) the group's lesson plan. Then, the next group member(s) implemented (I) the second section of the group's lesson plan in the class. Every group went through the *Reflect(R)* and *Revise(R)* stages again. The

IRR stages in this study worked a total of three times in every group, which gave the participants several opportunities to experience learning by design.

Data Analysis

To examine whether the IDDIRR model had impact on improving TPACK and how the model worked, data were analyzed in two ways. First, we used the straightforward description approach (Wolcott, 1994) to present the instructor's observation field notes collected during the *Introduce* and *Demonstrate* stages. The approach is to show the data as they were originally recorded (Simons, 2009). Thus, the instructor's observation of the participants' learning process was presented to readers as the events occurred in the class. The participants' written materials that were also collected during these two states were used as supplemental resources to enhance the observation data. Then, the descriptive statistics were used to present the results of the mid-TPACK survey that was conducted after *Introduce* and *Demonstrate* to understand the effects of the two stages.

Second, we applied content analysis to analyze data collected during the *Learning TPACK by Design* activities—groups' lesson plans and digital artifacts, students' written materials, and the instructor's field observation notes. Since this study was to understand the participants' learning processes of TPACK, the precoding strategy was considered suitable for this study to analyze data (Simons, 2009). The precoding strategy is also known as the deductive category application (Mayring, 2000) by which precodes can be generated from the theoretical framework. Accordingly, the categories of this study were derived from the seven domains of TPACK. The definitions, examples, and coding rules for each deductive category are shown in Table 2.3. After the data were coded based on the categories, we examined and compared the categories carefully to identify themes and find patterns from the data. Finally, we also applied a paired t-test method to compare the participants' responses to the mid- and post-TPACK surveys so as to examine the effects of the *Learning TPACK by Design* activities.

Table 2.3

A Categorization Matrix for Data Analysis in Learning TPACK by Design Activities

Category	Definition	Example	Coding Rules
Pedagogical Knowledge (PK)	An understanding of strategies and methods that can be used to facilitate teaching practice and students' learning	"Students need to learn hands-on activities. Group work would help." "I would incorporate an assessment to see what my students learned."	Demonstrating abilities to identify or use appropriate teaching methods
Content Knowledge (CK)	An understanding of a subject matter in which the knowledge of concepts, theories, and structures of a discipline are included	"What exactly a cell is and the general function of a cell in an organism." "The physical features and characteristics of living and nonliving things."	Demonstrating a deep understanding of the structure and content in the selected topic
Technological Knowledge (TK)	An ability to master and use a variety of digital technologies to accomplish a task	Create an online learning space or digital artifacts.	Demonstrating abilities to use different technologies to create digital artifacts
Pedagogical Content Knowledge (PCK)	An understanding of how to represent subject content with suitable teaching methods	"We should give a pre-quiz before the lesson to assess how much the students know prior to the lesson."	Demonstrating abilities to teach the content in consideration of students' needs or backgrounds
Technological Pedagogical Knowledge (TPK)	An ability to evaluate advantages and limitations when using technologies to teach specific learning activities	"Using an [online] quiz at the end of the lecture is a good way to evaluate the students. It is much faster than grading paper quizzes and allows us to see almost immediately what the students still need to learn."	Demonstrating abilities to use technology appropriately based on students' learning needs

Technological Content Knowledge (TCK)	An ability to identify topics with high need for technology and to represent the content using suitable technology	"PowerPoint is not necessary to learn the content [living and non-living things] and not necessarily the most engaging. Try and find a technology that does more than enhance the lesson."	1. Demonstrating abilities to identify the necessity of using technology in the selected topic 2. Demonstrating abilities to apply appropriate technology to represent topics that are difficult to teach using traditional methods
Technological Pedagogical Content Knowledge (TPCK)	An understanding emerges from interactions among the knowledge of technology, pedagogy, and content	"The lesson started out with testing the students' prior knowledge of the days of the week. Showing the video of the days helped instill a song in the students' head to help them remember the order."	1. Demonstrating abilities to identify the necessity of using technology in the selected topic and based on students' needs 2. Demonstrating abilities to use suitable technology to teach the content that is difficult to represent by traditional means and teach the content with appropriate methods

Validity and Reliability

To increase the validity and reliability of this study, we applied three strategies—data triangulation, peer examination, and the statement of researcher's bias (Merriam, 1995). First, data triangulation refers to the usage of several data sources. We triangulated qualitative data such as lesson plans, written materials, etc. with TPACK surveys. Second, peer examination served as a confirmatory approach to improve the research validity. The two researchers discussed regularly the theoretical foundation of the study, the design and implementation of the model, and the plausibility of emerging findings over two years. Third, it is important in qualitative studies that researchers learn the strategy of "remov[ing] themselves from the picture, [and] leaving the setting to communicate directly with reader" (Wolcott, 1994, p.13-14). We reflected on our roles in this study; specifically one of the researchers' role was dual—a researcher and an instructor. We acknowledge that the interpretation of the case likely includes the instructor's perspectives since it was difficult to place a particular dual role outside of the study because they both emanated from the same source. However, the reflection on the subjectivities the instructor brought to the study enabled us to be aware of the reported findings throughout the research process.

Findings

The findings are described based on the two main learning activities of the model—the *Introduce* and *Demonstrate* stages and the *Learning TPACK by Design* activities.

The *Introduce* and *Demonstrate* Stages

Introduce. The TPACK figure, definitions, examples, and brief explanations for the seven domains of TPACK were introduced in this stage. However, this stage focused on the instruction of CK, PK, and TK mainly since most of the participants had not taken education-related courses prior to this class. Helping them understand the three knowledge domains was to facilitate their later learning of integrated knowledge of TPACK (e.g., TCK, TPK, etc.).

The instructor planned to teach the concepts within two weeks (Week 2-Week 3), while the teaching was prolonged (Week 2-Week 5) because the participants had difficulties understanding PK. The participants had no difficulty understanding TK. They were taught to relate the concept to their everyday technologies and the technologies that they were learning at that time, such as Web 2.0 tools, Internet search engines, emails, Google Site, etc.

With regard to CK, the instructor suggested that the participants connected CK to the content in their majors. Next, the instructor used the state performance standards and explained that a teacher possessing CK can teach the subject content that meets the performance standards. Then, questions relevant to CK were asked to assess the participants' learning, such as "When you apply state performance standards to design a lesson plan, what knowledge do you use, andwhy?" Ten out of 15 participants grasped the meaning of CK by providing accurate responses. For example, "the standards say what content these students need to learn" (Participant 1, written materials) and "When a teacher finds standards they use content knowledge because they are finding the content they wish to address" (Participant, 12, written materials).

The participants experienced difficulty understanding PK. The instructor explained the meaning of PK and provided a list of teaching methods to help the participants' learning of PK. During the class discussion, the instructor observed that the participants did not know why different teaching methods could result in different learning results and how to apply appropriate teaching methods to promote student learning. The instructor provided a list of teaching methods and asked the participants to pick the teaching methods that they had experienced in class before, such as the jigsaw method, class discussions, and group discussions. Then, the instructor guided the participants in discussing and reflecting on these methods from students learning perspectives. Their understanding of PK was then observed in an assignment in which they designed a teaching activity. For example:

> I will first introduce fractions, decimals, and percentages to the students…I will also be sure to make it clear that not only do I want the students to be able to accomplish these tasks, but I want them to be able to explain their solutions to me and to their peers…

> They will each be expected to explain their thought processes to their partner so that each student can understand how others might think about a particular problem. (Participant 6, written material)
>
> I introduce the lesson by showing a news clip on the health issue at hand. After the clip is finished I explain to the class what the news clip was trying to say to clarify any loose ends. Then, I assign the class into groups to research different parts of the health issue to prepare for the debate [activity]. As the students are in groups researching, I will walk around the class asking the students what they are researching and answer any questions they may have. (Participant 10, written material)

However, the instructor observed that the participants did not have a *deep* understanding of PK and CK. For instance, after the participants had a basic understanding of PK and CK, the instructor selected a state performance standard from mathematics (e.g., recognize and apply mathematics in contexts outside of mathematics) and explained that the standard implies that a teacher should possess PK, using appropriate methods to facilitate students to apply knowledge outside of the classroom, so as to achieve the subject goal (CK). However, the participants were confused with the pedagogical elements (PK) within a content standard (CK). In other words, they had difficulties identifying or differentiating PK and CK when the two concepts were integrated in an example (e.g., in the PCK format).

Demonstrate. Integrated knowledge of TPACK (e.g., TCK, TPK, etc.) was instructed in the *Demonstrate* stage in Week 7. The instructor offered a technology-integrated teaching example (the comparison of using Photo Story and Wikipedia as tools to teach the Civil War) instead of merely providing definitions of integrated domains of TPACK. Photo Story was chosen because the participants had completed a Photo Story project in which they created a story about themselves (possessing TK).

After the demonstration, the instructor asked the participants to evaluate and compare the two technological tools with regard to how the tools support the learning of the content. During the class discussion, the instructor observed that the participants had difficulties evaluating the two tools in consideration of students' learning needs. For example, with regard to Wikipedia, the participants mentioned that the tool provided sufficient information for the learning of the American Civil War. With regard to Photo Story, they tended to evaluate it based on its external characteristics such as gaining students' attention, increasing learning interest, etc. None of them provided comments based on the tool's pedagogical affordances (relevant to the domains of TCK, TPK, and TPACK), such as Photo Story was a tool that is more effective than Wikipedia in presenting the content because it can be created based on students' grade levels and engage students in a virtual context of a historical event. Thus, it was concluded that the building of participants' integrated knowledge was not observed in the *Demonstrate* stage.

Quantitative data from the mid-test TPACK survey that conducted after the *Introduce* and *Demonstrate* stages was used to examine the effects of the stages as well as triangulate the qualitative data. Table 2.4 listed the means and standard deviations of the mid-test scores of the participants' self-assessed TPACK. The mean scores of all the seven domains were high (around 4 out of 5). These scores were not consistent with the instructor's observation in the class. As described previously, the participants had a basic understanding of PK and CK but failed to differentiate the two concepts and their integrated knowledge was not built. The scores seemed to have measured the participants' *perceptions* and/or beliefs about their knowledge rather than their *actual* knowledge.

Table 2.4

Means and Standard Deviations of Respondents' Self-Assessed TPACK (n=15)

	Mid-test		Post-test	
TPACK domains	M	SD	M	SD
TK	4.22	.413	4.21	.322
PK	3.9	.533	4.04	.526
CK	3.51	.442	3.69	.428
TPK	3.81	.385	4.20	.555
TCK	3.80	.528	4.02	.483
PCK	3.73	.517	3.92	.455
TPACK	3.92	.742	4.32	.671

* Possible range of score (1-5)

The *Learning TPACK by Design* Activities

The class was separated into four groups with five people each to carry out the *Learning TPACK by Design* activities—*Develop, Implement, Reflect,* and *Revise*. The report of the findings here focuses on the participants' learning of TCK, TPK, and TPACK because the themes derived from these domains revealed meaningful interrelationships.

1. Only one group identified a suitable topic that needs technology to support the presentation of the content, while the group did not use appropriate technology to teach the content (TCK was not built successfully).

In terms of the coding scheme, the analysis of TCK refers to the knowledge including whether the participants identify the topics that are difficult to teach using traditional methods[6] and whether the participants apply appropriate technologies to support the presentation of the content. Table 2.5 shows the topics that the four groups identified for their teaching practice and the technologies used in teaching. The topics identified by Group 1 (days of the week, holidays,

[6] Technologies can be used as supportive tools in any subject area or topic for efficient or convenient purposes. However, in this study, we emphasized effective use of technology for student learning than efficient use of technology for teachers.

and months of the year), Group 2 (living and non-living things), and Group 4 (multiplication for five, nine, and ten) were the topics that are not difficult to teach in traditional classrooms. We expected that some sub-topics for Group 2 would need technology to support if higher-order thinking questions were designed, such as “Why is water a non-living thing even though it can flow?” or “Why are trees living things even though they can’t move?” However, the group used technology (e.g., online games) on discriminating living objects from non-living objects for lower-level cognitive activities.

Table 2.5

Groups’ Teaching Topics and the Technology Used

Group	Topic	Technology used
Group 1	days of the week, holidays, and months of the year	videos, online games, and online quiz
Group 2	living and non-living things	videos, online games, PowerPoint, and online quizzes
Group 3	cells	videos, PowerPoint, and online quiz
Group 4	multiplication for five, nine, and ten	videos, PowerPoint

Group 3 taught the topic of cell structures of plants and animals to the class, which is a topic that is difficult to teach using traditional methods. However, Group 3 did not use appropriate technologies to present the content. Members of this group played videos regarding cell structure to gain attention and used PowerPoint presentations to teach the main content. We expected that this group could use technologies learned in the class to represent the abstract concepts, such as concept-mapping tools for the comparison of cell structures. However, we did not find sound evidence of their TCK learning. From the reflection of the lesson plan, this group mentioned that “because of the content, it was difficult to find interactive activities and games for the students”. These results showed that the participants had difficulty applying appropriate technology to a high technology-need topic.

2. All the four groups used teacher-centered strategies of technology application (TPK was not built successfully)

The analysis of TPK refers to the knowledge whether the participants apply appropriate technology in teaching based on students’ learning needs. Table 2.5 shows the technology used by each group when they implemented teaching in the class. Technologies used by the four groups were limited to videos, PowerPoint presentations, online games, and online quizzes. In addition, these technologies were applied in a similar pattern across the four groups—videos for gaining students’ attention, PowerPoint presentations for introducing the content, online games and online quizzes for assessing students’ factual knowledge. Students were not provided opportunities to manipulate technologies to develop higher-order cognitive skills or create artifacts to show their learning processes and outcomes. In other words, teacher-centered strategies dominated the teaching process in which technologies were used to present content or enhance lecture efficiency.

3. The participants’ understanding of TPACK was the combination instead of the integration of knowledge:

The lesson plans created by the four groups demonstrated the *combination* of technology (e.g., videos, PowerPoint, on-line quizzes, etc.), pedagogy (e.g., discussion, interactive activities, lectures, etc.), and content, instead of the *integration* of the three. For example, from the groups’ lesson plans and written materials collected at the end of the semester:

I think we incorporated all three aspects: technology clearly in the video and game, pedagogy in the mind mapping together and content knowledge in the teaching of the months, seasons, and holidays. (Group 1, lesson plan)

We had students use technology by watching a video and identifying living and nonliving things. Pedagogy was addressed in that we taught the students through technology and an interactive game. (Group 2, lesson plan)

The first two videos were a great way to help the student's get interested in the subject and to immediately capture their attention….. They seemed to add a lighthearted and engaging mood to the lesson, which is definitely needed in 7th grade students. (Group 3, lesson plan)

Technology was the video and PowerPoint which all parts of the group had. Pedagogy was teaching the tricks to multiplication and using a worksheet to review. Content was the multiplication tables. (Group 4, lesson plan)

[TPK is] having students use Inspiration [tool] to make a mind-map. (Participant 14, written material)

[TCK is] using PPT to teach content lesson. (Participant 11, written material)

[TPACK is] having students work in groups to make a PowerPoint about the content they're learning. (Participant 14, written material)

These excerpts showed that the participants' TPACK were at the stage of combining the core knowledge of TK, PK, and CK. They did not give clear explanations of why and how technologies could make the content easier for students to understand. For quantitative results, see Table 2.4 for the means and standard deviations of the mid-and post-test scores of the participants' self-assessed TPACK. Most of the means among the seven knowledge domains increased; however, a paired t-test indicated that only TPK (t [15] = -3.075; p =.005) revealed a significant difference. We triangulated data and found that the statistics revealed the participants' self-perceptions of TPACK more than their actual abilities. For example, the mid-and post-test scores of TPK were high (M=3.81 and. M=4.2). However, the qualitative analysis showed that the participants' TPK was not built successfully since the application of technology was mainly teacher-centered. Similarly, the scores of TPACK were high (M=3.92 from the mid-test and M=4.32 from the post-test), while the performance of TPACK was not identified clearly by the researchers. Similar to our interpretations of the mid-test scores after the *Introduce* and *Demonstrate* stages, the TPACK surveys seemed to evaluate the participants' self-perceptions of TPACK rather than their actual abilities of TPACK.

Discussion

This study drew on the *Learning by Design* approach and attempted to provide preservice teachers with iterative opportunities to design, develop, implement, reflect, and revise a lesson plan so as to help them acquire TPACK expertise and skills. The summary of the findings are as follows.

1. In the *Introduce* and *Demonstrate* stages, the participants built a *basic* understanding of TK, PK, and CK, while their understanding of integrated knowledge of TPACK (e.g., TCK, TPK, & TPACK) was not built.
2. In the *Learning TPACK by Design* activities, the participants' understanding of TCK and TPK were not observed in the lesson plans they created. Their understanding of TPACK was the *combination* of TK, PK, and CK instead of the integration of the three.

The IDDIRR model did not result in satisfactory findings. However, this study provides initial guidelines for instructing TPACK in a multidisciplinary technology integration course and informs future research of the barriers that they may confront in similar settings. If the participants were from education majors with prior knowledge of pedagogy, the effects of the model may have been different. However, when the majority of students in a technology integration course are from education majors, their pedagogy-related knowledge could vary a lot. As described earlier, more than 50% of teacher training programs have provided technology integration courses that are *not* based on educational methods or subject matters (National Center for Education Statistics, 2008), which implies that the course mixes education majors from different subject areas with different levels of pedagogy-related knowledge. Thus, technology integration in such settings (e.g., multidisciplinary technology integration courses) should consider the disparity of pedagogy-related knowledge among learners and provide them with appropriate learning activities.

Second, the presupposition of IDDIRR was that TPACK acquisition should be built on the mastery of the seven domains of TPACK. That is, learners should clearly understand the isolated domains; then they can understand the interplay among the domains. The findings showed that this presupposition was the case in this study because preservice teachers' lack of pedagogy-related knowledge affected their TPACK learning. For example, as reported earlier, preservice teachers tended to evaluate technological tools (i.e., Photo Story vs. Wikipedia) from its external characteristics (e.g., gaining attention) instead of considering how to use the tools to better support students' learning (e.g., engaging them in a virtual historical environment). These findings imply that the lack of pedagogy-related knowledge was critical to TPACK acquisition. It also suggests that TPACK acquisition requires a progressive learning process that proceeds gradually from isolated knowledge to integrated knowledge.

Finally, lesson plans created and implemented by the preservice teachers provided more valid data than the surveys to assess preservice teachers' *actual* abilities of TPACK. It was likely that preservice teachers' lack of pedagogy-related knowledge limited the self-assessment of their actual TPACK capacity. We acknowledge that the assessment of learning should include the opportunity for learners to apply their new knowledge or skills in actual settings (Gagné, Wager, Golas, & Keller, 2005; Gustafson & Branch, 2002; Merrill, 2002, 2007, 2009). In this study, because preservice teachers were provided opportunities to develop and teach lesson plans, their actual understanding of TPACK was empirically observed. Thus, artifacts created by preservice teachers for practice or implementation purposes served more valid data than surveys (self-perceived data) to present the preservice teachers' TPACK learning.

Re-design of the Model

In addition to investigating how the IDDIRR model enhanced preservice teachers' TPACK, another goal of this study was to refine the model based on the empirical findings. Our model did not take the participants' teaching-related background or knowledge into account, which affected their learning of the interrelated knowledge of TPACK. In the next model, each steps of IDDIRR should be modified to involve pedagogy-enhancing elements so as to facilitate the learning of the domains of TPACK. For example, during the *Introduce* stage, instead of telling preservice teachers the meanings and examples of TPACK, the instructor should allow preservice teachers to *actively* discuss meanings and create examples by themselves. During the *Demonstrate* stage, more examples such as good lesson plans and TPACK-integrated teaching examples for different subject areas should be demonstrated (Gibbons, n.d.; Shute, Jeong, Spector, Seel, & Johnson, 2009, Seel, 2003), and then preservice teachers should discuss and identify how technology affords the teaching/presentation of the content. This revision aligns with the principles that effective instruction should demonstrate *how-to* do the task as well as show *what-happens* of the tasks that learners will engage in (Merrill, 2007).

When preservice teachers carry out the *Learning TPACK by Design* activities, preservice teachers can learn to develop a lesson plan integrating one technology that they have learned in the class into their interest subjects. After developing several lesson plans that require them to integrate many different technologies, it is likely that their teaching-related knowledge improves. Then, preservice teachers can learn to integrate several different technologies into a comprehensive lesson plan that is supposed to further enhance their abilities to integrate technology effectively.

Limitations of the Study and Future Research Directions

There are limitations to our present study that should be considered in future research. First, this study did not consider the participants' insufficient teaching-related knowledge when designing and implementing the IDDIRR model. Thus, they had difficulties understanding TPACK and demonstrated mostly teacher-centered strategies in teaching practice. If the model included activities to enhance pedagogy-related knowledge, preservice teachers' improvement or difficulties of TPACK learning in each IDDIRR stage may have been more clearly identified and observed. Future research should involve pedagogy-enhancing elements in the model or training programs so as to facilitate the acquisition of TPACK.

In addition, this study did not include a treatment to deal with the lack of targeting participants (preservice teachers) as well as the mix of education and non-education majors. In order to better understand the effects of the model in a multidisciplinary technology integration course, future research should apply other methodologies of sampling. For example, sampling can be conducted in different class sections of a multidisciplinary course to group participants into same subject majors, different subject majors, different grade levels, mixing with non-education majors, etc. It should be noted that the focus of the design is to respond to the various conditions that may happen in multidisciplinary courses (e.g., including non-education majors). The sampling approach is also conducive to improving the validity of the study.

Implications

It is a challenging task to teach preservice teachers' TPACK when they did not possess pedagogy-related background and their subject majors were diverse. Although this initial model had limited effects on improving preservice teachers' TPACK, this study identified important practical difficulties that future research may confront and provided potential methods to overcome. While TPACK is a conceptual framework that emphasizes the interplay of the seven domains of knowledge, the study findings also suggest that a lack of knowledge in any domain hinders the understanding of the whole knowledge, TPACK.

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CHAPTER 3

THE SECOND PROTOTYPE OF THE DEVELOPMENT OF A TPACK-BASED INSTRUCTIONAL DESIGN MODEL: AN IMPLEMENTATION STUDY IN A TECHNOLOGY INTEGRATION COURSE[1]

[1] Lee, C. J. & Kim, C. A modified version of this chapter will be submitted to *Journal of Teacher Education.*

Abstract

Prototype II of the Technological Pedagogical Content Knowledge (TPACK) based instructional design (ID) model has been developed based on the findings from the implementation study of Prototype I. The model was applied in teaching a technology integration course with 38 preservice teachers. A case study approach was used in the implementation study of Prototype II. Data were collected from the participants' discussion worksheets and lesson plans along with associated artifacts, videos recorded teaching practice, and the researcher's field observation notes. Data analysis results revealed that: (a) preservice teachers' basic understanding of TPACK was built through discussions on the meaning of TPACK as well as evaluations of technology-integrated teaching examples; (b) designing several technology-integrated lesson plans improved preservice teachers' teaching-related knowledge and facilitated their TPACK learning; and (c) preservice teachers' use of technology was more teacher-centered than student-centered. Findings are discussed along with suggestions and future research possibilities.

Keywords: technology integration, TPACK, instructional design model, preservice teacher education, learning by design

The Second Prototype of the Development of a TPACK-Based Instructional Design Model: An Implementation Study in a Technology Integration Course

This study presents the second prototype (Prototype II) of the design-based research that aims to develop a TPACK-based ID model to improve preservice teachers' TPACK (Technological Pedagogical Content Knowledge). This study is the follow-up research of Prototype I—the TPACK-IDDIRR model (standing for the stages *I*ntroduce, *D*emonstrate, *D*evelop, *I*mplement, *R*eflect, and *R*evise) (Lee & Kim, under review). IDDIRR is a model that was developed to improve preservice teachers' TPACK for preservice teachers with different majors enrolled in multidisciplinary technology integration courses. Prototype I had been applied to and evaluated in a technology integration class. That experience informed the design and implementation of Prototype II.

The implementation of IDDIRR yielded two key findings. First, the preservice teachers showed improvement in their TK (technological knowledge), PK (pedagogical knowledge) and CK (content knowledge), while no explicit evidence of improvement was discovered in integrated knowledge (TPK, TCK, and TPACK)[2]. For example, preservice teachers demonstrated an online game involving living and non-living things, and they referred to that as TCK because they thought that an online game (which might be thought of as an instance of TK) could be used to present learning content (CK). Their understanding of integrated knowledge (TPK, TCK or TPACK) was limited to simply combining technology, pedagogy, and content rather than integrating them coherently and seamlessly in a unit of instruction. This distinction is similar to a distinction between a lesson that involves multiple media (e.g., first a video clip, and

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[2] It should be noted that TPACK is typically considered an inherently integrated concept and cannot be meaningfully deconstructed into separate components. However, when one examines how teachers developed the integrated understanding, knowledge and skills associated with TPACK, it is meaningful to see how teachers are progressing along a number of enabling dimensions, which is an underlying assumption of these studies.

then a PowerPoint presentation, and then a discussion forum) as opposed to a multi-media lesson that interleaves such things together in a mutually supportive manner. While it does take effort to select individual media items to include in a lesson, it takes much more design effort to interleave those things so that the learner is seamlessly engaged in an ongoing learning process. As emphasized by Mishra and Koehler (2006), a teacher's TPACK should involve an understanding of the relationships among the three types of knowledge and how they will engage learners and mutually support learning.

Another finding was that preservice teachers' self-assessed TPACK was not aligned with their actual performance using TPACK on technology-integrated teaching tasks (e.g., technology-integrated lesson plans and teaching practice). While the participants perceived that they were capable of using technology effectively in teaching activities, a lack of integrated knowledge was observed in their performance, as discussed above. They rated their TCK, TPK, and TPACK either good or very good (i.e., either 4 or 5 out of 5), but their understanding of those domains were not evidenced in their technology-integrated teaching tasks.

The Prototype I implementation study findings guided this follow-up study emphasizing that teacher training programs should critically take preservice teachers' teaching-related backgrounds into consideration when improving their educational repertoire, such as technology integration. Clearly it is sub-optimal to simply demonstrate technologies and show teachers how to use them apart from a clear learning task with which the teachers can relate. Activating a teacher's pedagogical and content knowledge when introducing a technology appears to be an essential aspect of developing TPACK, as suggested by the first study. This emphasis is also consistent with Shulman's (1987) notion that preservice teachers' insufficient knowledge of the relationship between pedagogy and content could hinder their teaching practice. Without an adequate knowledge base with regard to pedagogy and content, teachers tend to experience difficulty applying appropriate methods to teach certain types of content (Shulman, 1987). The revised TPACK model (Prototype II) included activities aiming to enhance pedagogical understanding and experience for the participants who lack the pedagogical knowledge thereof so as to facilitate development of their TPACK. The goal of this study was to determine to what extent a revised prototype and approach to developing preservice teachers' TPACK was effective. The specific objectives of this study were to: (a) develop Prototype II of the TPACK-based ID model based on the findings of Prototype I, (b) apply Prototype II to a technology integration course to investigate its effects on the improvement of TPACK, and (c) provide suggestions for the revision of Prototype III and future research possibilities.

Theoretical Framework

Prototype II of the TPACK-based ID model proposed in this study was grounded in: (a) design-based research (Amiel & Reeves, 2008; DBR Collective, 2003; Reeves, 2006; Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006), (b) TPACK (Mishra & Koehler, 2006), (c) the *Learning by Design* approach (Kalantzis & Cope, 2005), and (d) instructional design models (Angeli & Valanides, 2005; Gagné, Wager, Golas, & Keller, 2005; Gustafson & Branch, 2002).

Design-Based Research

Design-based research (DBR) is a methodology that is considered a promising approach to solving complicated problems in educational settings (Reeves, 2006; van den Akker, 1999). Studies that apply DBR involve the iterative design, development, and evaluation of interventions (e.g., programs, strategies, materials, etc.) with active and ongoing interaction with context practitioners with the end goal of deriving practical, optimal and scalable solutions to educational problems (Plomp, 2007). Findings from DBR efforts help to ensure the accessibility and feasibility required for effective educational usage. Prototype II of the TPACK-based ID model presented in this study is the second iteration in this DBR effort that aims at promoting preservice teachers' effective technology integration. Drawing on DBR, the development of Prototype II was based on the suggestions from the Prototype I implementation study, and the findings of this implementation study will also provide suggestions for revision for the next iteration (Prototype III).

TPACK

TPACK is an acronym standing for Technological Pedagogical Content Knowledge, which is a theoretical framework to enhance educational practice, especially preservice teachers' knowledge of technology integration in teacher training and professional development programs (Koehler & Mishra, 2009; Mishra & Koehler, 2006). The three knowledge bases of TPACK are content, pedagogical, and technological knowledge. TPACK emphasizes the interplay of the three knowledge bases as opposed to considering them in isolation. The interplay of the three knowledge bases, viewed from a developmental perspective, comprises seven types of knowledge: content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK). TPACK is the proficiency-level (more than simple competence) knowledge that teachers should possess because it integrates all three knowledge bases with seamless interaction among all seven types of developmental knowledge. When teachers possess TPACK, they understand how to represent and support learning specific content with appropriate pedagogy and technology, which is to say that the question of how best to teach involves all three types of knowledge taken into consideration together.

The *Learning by Design* Approach

Learning by design is part of the theoretical foundation for this study as it provides a point of departure for developing TPACK in pre-service teachers. Design is a process of problem solving (Silber, 2007). Problems during a design process are often complex and ill-structured and include a series of cognitive tasks that require designers to identify and analyze problems, explore and evaluate solutions, and make decisions (Jonassen, 2008; The UK Technology Education Centre, n.d.). The *learning by design* approach encourages teachers to take the role of designers of learning activities (Goodyear, 2001; Kalantzis & Cope, 2005; Kali, Levin-Peled, & Dori, 2009; Yoon, Ho, & Hedberg, 2006). The approach is especially important in the digital era, as exemplified by the following statement from Kalantzis and Cope (2005):

> The need for a new approach to learn arises from a complex range of factors—among them, the changes in society and the economy; the potential for new forms of communication made possibly by emerging technologies; and rising expectations amongst learners that education will maximize their potential for personal fulfillment, civil participation and access to work. (p.v)

Since technologies provide opportunities to offer innovative ways for students to engage, relate, and communicate, preservice teachers should participate in designing dynamic learning artifacts, resources and activities to meet learning needs in representative schools and among typical students (Kalantzis & Cope, 2005). The *Leaning by Design* approach was applied to the proposed ID model in this study to equip preservice teachers with the ability to design technology-integrated activities and create digital artifacts.

Instructional Design Models

The instructional design (ID) model is a systematic design process, which can help maximize the effectiveness of educational and training programs so as to facilitate learning (Andrews & Goodson, 1980; Branch, 2009; Gagné, Wager, Golas, & Keller, 2005; Gustafson & Branch, 2002). ID models typically include the elements of analysis, design, development, implementation, and evaluation. However, these elements are not unchangeable. Instructional designers modify the elements to meet specific instructional purposes. For example, some ID models had been proposed to improve preservice teachers' technology integration or TPACK (Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010). However, these models were particularly designed for or investigated in specific subject areas such as science. To address the need from the reality that technology integration courses enroll preservice teachers from diverse subject majors (National Center for Education Statistics, 2008), this study incorporates the characteristics of traditional ID models as well as draws on several principles of instruction (Merrill, 2002, 2009) to develop an effective model for preservice teachers' TPACK learning in a multidisciplinary technology-integrated course.

Design Principles and the Revised Model

Design Principles

One critical characteristic of design-based research is to conduct "rigorous and reflective inquiry to test and refine innovative learning environments [interventions] as well as to define new design principles" (Reeves, 2006, p. 95). Design principles serve as guidance for researchers to develop and test plausible solutions or interventions for research problems. The findings from the implementation study of Prototype I of the TPACK-based ID model led to revisions in design principles for the Prototype II model. Table 3.1 shows the comparison of the design principles of the two prototypes.

Table 3.1

Design Principle Changes in the TPACK-based ID Model

Design Principles in Prototype I	Change	Design Principles in Prototype II
Principle 1. Explicit and systematic procedures: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.	No change	**Principle1. Explicit and systematic procedures**: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.
Principle 2. TPACK introduction and demonstration stages: Introducing the TPACK theory can build preservice teachers' knowledge base of technology integration, and demonstrating technology-integrated examples can prepare them for designing technological teaching artifacts.	Includes the changes to improve pedagogy-related knowledge	**Principle 2.Understand TPACK:** Preservice teachers' discussion of definitions, creation of examples, and comparison of teaching examples regarding TPACK can enhance understanding of the domains of TPACK.
Principle 3. Design-based learning activities: Creating a lesson plan and a corresponding digital artifact can prompt preservice teachers to analyze the subject content and learning needs of students.		**Principle3. Engage in TPACK:** Opportunities for preservice teachers to develop, discuss, and revise a lesson plan for each of the technological tools can enhance the connection of technology to a specific subject and pedagogy.
Principle 4. A cyclic design-based learning process: Opportunities for preservice teachers to go through the design process—implementation, reflection, and revision of a lesson plan and a corresponding digital artifact—can enhance the learning of TPACK.		**Principle 4.Practice TPACK:** Opportunities to integrate several technologies to develop a lesson plan and opportunities to implement, reflect, and revise the lesson plan help transfer knowledge to practice.

The Prototype I implementation study findings indicated that strategies to enhance preservice teachers' teaching-related knowledge should be used to improve their TPACK. Preservice teachers' lack of pedagogical experience and knowledge could hinder their understanding of the multiple interactive relationships among technology, pedagogy, and content. Thus, in the current study, the revised design principles were to provide preservice teachers with teaching-related experience when learning TPACK, such as viewing and comparing technology-integrated teaching examples and developing several technology-integrated lesson plans.

Comparing the design principles of the two prototypes, Principle 1 was retained in Prototype II since systematic procedures are crucial elements of an effective ID model (Branch, 2009; Gustafson & Branch, 2002). Furthermore, the Prototype I implementation study findings did not suggest any problems or changes in this principle. The use for strategies that strengthen preservice teachers' teaching-related knowledge for their TPACK acquisition was emphasized in Principles 2, 3, and 4 of Prototype II. In accordance with Principle 2, preservice teachers actively discuss the definitions of TPACK, create examples for TPACK domains, and compare teaching examples based on TPACK instead of passively receiving information from the instructor as in Prototype I. In accordance with Principle 3, Prototype II is to engage preservice teachers in designing multiple technology-integrated lesson plans that aim at familiarizing themselves with teaching and learning activities as if they were K-12 teachers. In accordance with Principle 4, Prototype II not only includes a characteristic of Prototype I—practice the lesson plan—but also requires the incorporation of several technologies that test preservice teachers' comprehensive ability to select and implement appropriate technologies effectively within the context of specific content with targeted learners.

Principles 2, 3, and 4 are consistent with the instruction principles of *demonstration*, *application*, and *integration*, respectively, discussed by Merrill (2002). That is, preservice teachers discuss and evaluate technology-integrated teaching examples demonstrated to them (*demonstration*), design technology-integrated lesson plans (*application*), and integrate their TPACK knowledge into teaching practice (*integration*). The activities mentioned in Principles 2, 3, and 4 comprehensively engage preservice teachers in a problem-centered setting, consistent with the *problem-centered* principle (Merrill, 2002), that requires them to solve real world tasks that progress from simple to complex (e.g., evaluating the quality of teaching examples regarding technology integration, developing lesson plans, practicing lesson plans).

The Revised Model (Prototype II)

Based on the revised design principles, Prototype I of the TPACK-based ID model was revised to reflect active inclusion of these principles. The revised model comprises three major instructional steps, namely, *Understand TPACK*, *Engage in TPACK*, and *Practice TPACK* (see Figure 3.1).

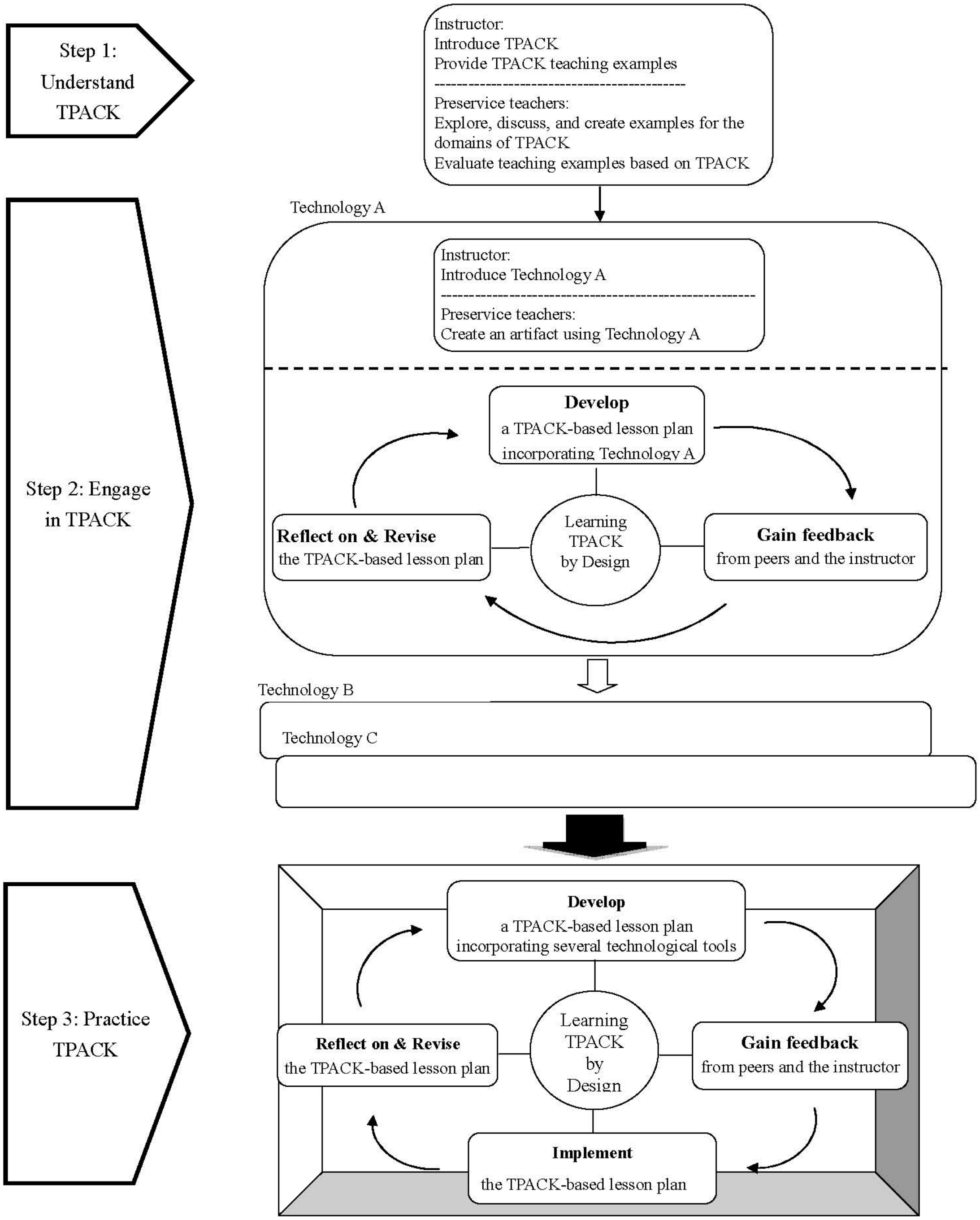


Figure 3.1. Prototype II of the TPACK-Based ID model

Step 1 is *Understand TPACK*, responding to design principle 2. This step is to prepare preservice teachers' understanding of technology integration as well as to enhance their teaching-related knowledge. Instead of being told the definitions of TPACK by the instructor, preservice teachers actively *discuss* and search for the meanings of TPACK. They also create examples for the domains of TPACK so as to become familiar with this concept. In this step, videos that include technology-integrated teaching examples are also presented. Preservice teachers *evaluate* and compare the examples based on their understanding of TPACK. Activities in this step not only introduce TPACK to preservice teachers but they also provide them with hands-on activities to explore TPACK. It is worth noting that the prototype to support preservice teacher development of TPACK is increasingly implemented as an example of TPACK in action, although the idea is to allow preservice teachers to notice this fact on their own.

Step 2 is *Engage in TPACK*. In response to design principle 3, this step aims at enhancing preservice teachers' understanding of TPACK as well as improving teaching-related knowledge by engaging them in designing several technology-integrated teaching activities. They create technological artifacts as well as lesson plans for each of the technologies that they have learned in the class. In other words, learning about and using technological tools go hand-in-hand in promoting technological knowledge (TK), which in this case can be considered skilled technological use. However, the design of lesson plans requires preservice teachers to consider other domains of TPACK, such as students' needs and content characteristics with technology.

In terms of Step 2, preservice teachers start with familiarizing themselves with a technological tool that has been introduced in the class by *creating an artifact* using the tool (e.g., Technology A). Then, they carry out the "*Learning TPACK by Design*" activity, in which three minor activities are included. They have to: (1) *Develop* a TPACK-based lesson plan by integrating specific technology (e.g., Technology A)—the development of a lesson plan can be carried out individually or in groups, depending on time management, class size, or other classroom factors, (2) *Gain feedback* from peers and the instructor, and (3) *Reflect on* and *Revise* the lesson plan accordingly. The same activities are repeated after the learning of a new technological tool (e.g., Technology B, C, etc.). Engaging preservice teachers in designing several lesson plans should provide them with a better understanding of the relationships of technology to content and students' learning.

Step 3 is *Practice TPACK*, responding to the design principle 4. This step is to transfer preservice teachers' understanding of TPACK to practice. This step also comprises *Learning TPACK by Design*, but there are two differences compared to Step 2. One is that Step 3 requires preservice teachers to incorporate several technologies that they have learned in the class or explored by themselves into the final lesson plan. The other difference is that the *Implement* activity is added to Step 3, and it requires preservice teachers to implement their final lesson plans in the class. The *Implement* activity can engage preservice teachers in an authentic teaching environment and is intended to help them realize technology integration at a deeper level.

Implementation Study

The specific objectives of this study were to develop Prototype II of the TPACK-based ID model based on the revision of Prototype I and to examine its effects on improving preservice teachers' TPACK. The following questions were investigated:

1. What are the effects of Prototype II of the TPACK-based ID model on preservice teachers' TPACK?
2. How does the implementation study of Prototype II of the TPACK-based ID model inform the re-design of the TPACK-based ID model?

Methodology

A case study framework was applied to this study in order to determine if and how the revised model would impact preservice teachers' TPACK. A case study approach can guide researchers in (a) understanding complex social phenomena and gaining a holistic view of the phenomena, and (b) developing an in-depth description and analysis of the phenomena (Yin, 2009). The case study approach was applied so as to acquire a comprehensive understanding of how the intervention (Prototype II) works in teacher education— a complex social phenomenon.

Context and Participants

The Prototype II model was implemented in two sections of a technology integration course for preservice teachers taught by the researcher during the Spring semester of 2012 at a large southeastern university. Nineteen students enrolled in each section (Sections 1 & 2) and voluntarily participated in this study (34 female, 4 male). One participant was an inservice kindergarten teacher and is an undergraduate student. Two participants were science and mathematics education majors. The rest of the participants were from diverse majors, as follows: advertising, animal science, chemistry, child and family development, communication sciences and disorders, consumer economics, health promotion, international affairs, public relations, psychology, and recreation and leisure studies. Overall, 10 out of the 38 participants had taken or were taking education-related courses when they took this course. The age of one participant was 36, while the ages of the rest of the participants ranged from 19 to 24. The average of the participants' ages was 21 (SD = 3.06). Since most of the participants had no teaching-related background, the context for this prototype was similar to the context for Prototype I in that most of the participants had no teaching-related background, and tend to lack PCK.

The 3-hour credit course was 16 weeks long. Technological tools taught in the course were: (1) communication and collaboration tools (e.g., Google Docs, in2Books, podcasting tools, the GLOBE Program, Blogging tools, Delicious), (2) graphic software (e.g., floorplanner), (3) video making tools (e.g., Microsoft Photo Story, iMovie, Slowmation), (4) image editing tools (e.g., Picnik, Picasa, etc.), (5) concept-mapping tools (e.g., Inspiration and Bubbl.us), and (6) Google Site.

Procedures

The course was designed to follow the three steps of the prototype II ID model (*Understand TPACK*, *Engage in TPACK*, and *Practice TPACK*). Participants were informed of the course goals and scheduled tasks during the first week. They were also informed that they would not only learn technology but also learn to integrate technology into teaching contexts. Every participant created a Google website during the first week where they submitted all the course assignments including technological artifacts, lesson plans, class discussion forms, and group teaching videos.

Step 1—*Understand TPACK.* The formal introduction to the TPACK concept occurred in Week 5, after the participants had learned a few technological tools used in education (e.g., Google Site and floorplanner). To introduce TPACK, the instructor used a TPACK-introductory video in which the seven domains of TPACK were explicitly explained. Then, the participants themselves formed small discussion groups with 3-5 people each (both sections included five groups, M1-M5 in Section 1 and N1-N5 in Section 2) to work on TPACK Worksheet-1 (see Appendix 3.A), in which each group discussed their understanding of TK, PK, and CK by giving definitions and creating examples representing the three domains. TPACK Worksheet-1 only included the questions about TK, PK, and CK because the results of Prototype I showed that the participants with limited teaching-related knowledge had difficulties in understanding all of the domains of TPACK at this stage.

In Week 6, two class periods were spent to help preservice teachers learn more integrated knowledge of TPACK (focusing on TCK, TPK, and TPACK). The concepts were introduced using two videos: one showing an example of teaching with TPACK integration and the other showing a non-example. Video 1 (presented in class period one), an example of teaching with effective TPACK integration, showed that an elementary teacher shared her story about her use of technology (e.g., online interactive map) to help students learn abstract concepts (e.g., cardinal directions) using student-centered pedagogy (e.g., hands-on activities). In contrast, Video 2 (presented in class period 2), the non-example, presented a teacher who used an online game to introduce living and non-living things without utilizing the affordance of online games. After watching both videos, each group worked on TPACK Worksheet-2 to discuss questions regarding integrated knowledge of TPACK. The questions included “In what activities were students engaged when using technological tools (TPK)?”, “Why is the technological tool used by the teacher in the video helpful for that topic (TCK)?”, etc. (see Appendix 3.B for the rest of questions).

Step 2—Engage in TPACK. From Week 6 to Week 13, 13 class periods were spent to engage the participants in further development of their understanding of and ability to meaningfully deploy TPACK. This step focused on providing opportunities to the participants to create a lesson plan for each of the technologies that they had learned in the class so as to experience its educational potentials. Based on the activities of Step 2, for example, the instructor *introduced* Photo Story first, and then every participant *created a digital artifact* using Photo Story (http://www.microsoft.com/education/en-us/teachers/guides/Pages/digital_storytelling.aspx). Next, they engaged in *Learning TPACK by Design* activities. They were asked to *develop* a lesson plan incorporating Photo Story and discuss the lesson plan with peers and/or the instructor to *gain feedback*, and they had to *reflect on* and *revise* the lesson plan thereafter. In total, the participants engaged in three projects that had them go through the activities of Step 2 six times. The three projects are as follows: (1) Project 1 (individual work): Each participant explored one of the following technologies—blogging tools, podcasting, the GLOBE Program (http://www.globe.gov/), or in2Books (http://in2books.epals.com/login.aspx?ReturnUrl=%2fDefault.aspx)—and designed a lesson plan integrating the tool, (2) Project 2 (individual work on the digital artifact and collaborative work on the lesson plan): Each participant created an artifact using Photo Story and found peers to design a lesson plan integrating the tool, and (3) Project 3 (individual work): Each participant created four digital artifacts using four technological tools (e.g., Slowmation, image editing tools, concept mapping tools, online games, etc.) and developed four lesson plans that integrated the created digital artifacts respectively. Note that in Project 2 the participants worked with peers to design a lesson plan because the participants should be given opportunities to learn from peers and this design was also expected to broaden the participants' understanding of TPACK (five groups were formed in each section, X1-X5 in Section 1 and Y1-Y5 in Section 2).

Step 3—Practice TPACK. From Week 13 to Week 15, nine class periods were spent for the participants to engage in the activities in Step 3. The participants themselves created small groups with 3-5 people each to work on their final project (five groups were formed in each section, U1-U5 in Section 1 and V1-V5 in Section 2). In terms of Step 3, first, every group *developed* a lesson plan incorporating several technologies that they had learned in the class or explored by themselves. They had to *create corresponding digital artifacts* mentioned in their lesson plans. Each group also created a student Website for later teaching purpose, in which teaching activities and digital artifacts were inserted. Second, groups discussed teaching ideas with the instructor to *gain feedback*. A student Website example is included in Appendix 3.C. Third, every group taught the class using the student Website for 30-35 minutes, and all the group members were required to teach (*implement*). The rest of the classmates acted as students, and everyone gave feedback to the teaching group. Finally, each group *reflected* on the feedback and specified what parts of the original lesson plan should be *revised*. Figure 3.2 presents the activities of the three steps in which the preservice teachers were engaged to learn TPACK.

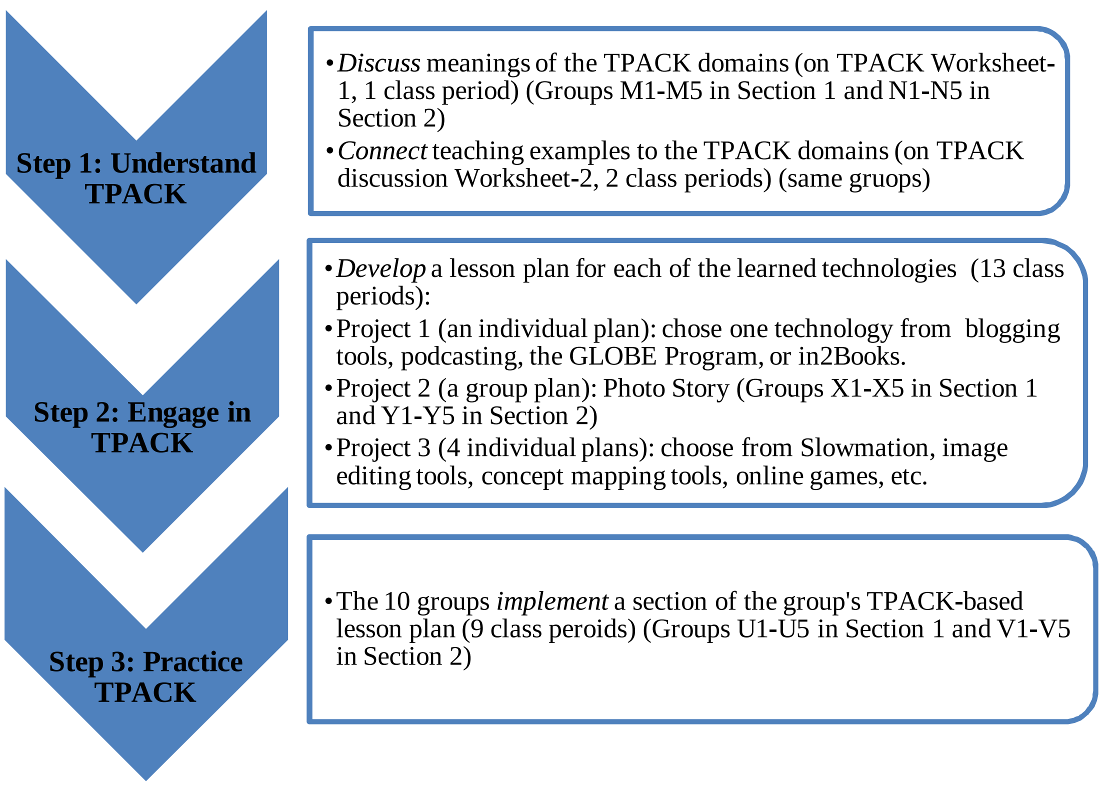


Figure 3.2. TPACK learning activities in three steps of the model

Data Collection

Data were collected based on the three steps of the Prototype II model and included: (1) TPACK discussion worksheets, (2) individuals' and groups' lesson plans and corresponding digital artifacts, (3) video-recorded groups' teaching implementations, and (4) the researcher's field observation notes. Table 3.2 presents the data sources along with the steps of the model and relevant research questions.

Table 3.2

Data Sources and Data Analysis

Research Questions	Steps of The Model	Data Sources	Data Analysis
RQ1: What are the effects of Prototype II of the TPACK-based ID model on preservice teachers' TPACK?	Step 1:Understand TPACK	-TPACK discussion worksheets, -researcher's field observation notes	description and analysis
	Step 2: Engage in TPACK	-individuals' and groups' lesson plans and corresponding digital artifacts, -researcher's field observation notes	deductive data analysis (the LoU framework)
	Step 3: Practice TPACK	-groups' lesson plans and corresponding digital artifacts, -videos recorded teaching -researcher's field observation notes	
RQ2: How does the implementation study of Prototype II of the TPACK-based ID model inform the re-design of the TPACK-based ID model?	N/A	-findings of RQ1	The analysis of the findings of RQ1

Data Analysis

In Step 1, *Understand TPACK*, the approaches *descriptio*n and *analysi*s (Wolcott, 1994) were applied. Simons (2009) explained *description* as "staying close to the data as originally recorded" (p. 121), and *analysis* as "moving beyond the purely descriptive to systematically identify key factors and relationships, themes and patterns from the data" (p.121). These two approaches are not mutually exclusive and can be blended to suit the research case (Simons, 2009). Data collected in Step 1 were the researcher's observation of the participants' TPACK discussion and the groups' written responses to TPACK Worksheets. D*escription* can provide a picture to readers regarding the researcher's observation. *Analysis* can help provide analytic data that transform the participants' responses to TPACK Worksheets into meaningful patterns and relationships.

In Step 2 and Step 3, *Engage in TPACK* and *Practice TPACK*, deductive reasoning (Mayring, 2000) was applied, and Levels of Use (LoU; Hall, Dirksen, & George, 2006) was used as a coding scheme for the deductive reasoning process. Each of the lesson plans was given one of the eight levels from the LoU framework to determine its level of applying innovation (technology integration). Table 3.3 lists the description of each LoU level. The LoU framework has been applied to measure the extent to which teachers actually use innovations, such as new curriculum, teaching materials, and technologies (Christou, Eliophotou-Menon, & Philippou, 2004; Ellsworth, 2000; Kim, Kim, Lee, Spector, DeMeester, 2013). Since this research attempted to understand the effects of the model on improving preservice teachers' TPACK, LoU was considered suitable to assess their TPACK learning that was observed in technology integration artifacts (i.e., lesson plans).

Table 3.3

The Coding Scheme

Levels of Use (LoU)[3]	Application of LoU to this Research[4]
0: Nonuse State in which the user has little or no knowledge of the innovation, no involvement with the innovation, and is doing nothing toward becoming involved.	*0: Nonuse* State in which the preservice teacher has little or no knowledge of technology integration into teaching, no involvement with the innovation, and is doing nothing toward becoming involved. For example: - A lesson is planned and/or implemented without the use of technology. - Instructional resources are limited to paper-based materials (e.g., worksheets).
1: Orientation State in which the user has recently acquired or is acquiring information about the innovation and/or has recently explored or is exploring its value orientation and its demands upon user and user system.	*1: Orientation* State in which the preservice teacher has recently acquired or is acquiring information about technology integration and/or has recently explored or is exploring its value orientation and its demands upon the educational system. For example: -The preservice teacher uses technology to *prepare* instructional materials (e.g., using a word processor to create worksheets), manage classroom tasks (e.g., sending emails, grading students' work, counting attendance, etc.), or make the instruction convenient (e.g., using a projector).
2: Preparation State in which the user is preparing for the first use of the innovation.	*2: Preparation* State in which the preservice teacher starts to use technology in teaching. For example: -The preservice teacher uses technology to support students' *understanding* or *comprehension* of the learning content using lower-level cognitive skills (e.g., memorization, organization). -Students are given opportunities to use technology to learn under preservice teachers' direction (i.e., teacher-centered strategies for technology integration).

[3] *Levels of Use* by G. E. Hall, D. J. Dirksen, and A. A. George, 2006, Austin: SEDL. Copyright © 2006, SEDL. Reprinted by Chia-Jung Lee with permission of SEDL).

[4] The identification of terms in LoU in corresponding to this research: *User* refers to *preservice teacher*; *innovation* refers to *the use of technology in teaching* or *technology integration*; *client* refers to *student*; *increase the impact* refers to *student learning.*

3: Mechanical use State in which the user focuses most effort on the short-term, day-to-day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than client needs.	*3: Mechanical use* State in which the preservice teacher focuses most effort on the *efficient* use of technology integration with little time for reflection. Changes in use are made more to meet the preservice teacher's needs than students' needs. For example: -The preservice teacher guides students in using technology to learn the content by means of constructing concepts, building in-depth understanding, doing scientific inquiry (e.g., exploring, analyzing, and synthesizing data), and thinking critically following the preservice teacher's instruction and direction (supporting higher-level cognitive skills using teacher-centered strategies for technology integration).
4a: Routine use Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving innovation use or its consequences.	*4a: Routine use* Use of technology in teaching is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving the use of technology or students' learning results. For example: -The preservice teacher consistently and regularly guides students in using technology to learn higher-level cognitive skills while starts to give students opportunities to select or explore technologies that are suitable for their learning (the beginning of student-centered strategies for technology integration).
4b: Refinement State in which the user varies the use of the innovation to increase the impact on clients within immediate sphere of influence. Variations are based on knowledge of both short- and long-term consequences for clients.	*4b: Refinement* State in which the preservice teacher varies the use of technology to improve students' learning within immediate sphere of influence. Variations are based on knowledge of both short- and long-term learning results for students. For example: -The preservice teacher is a facilitator of students' learning and supports students in deciding what technology can best facilitate or present their learning (high level of student-centered strategies for technology integration).

5: Integration State in which the user is combining own efforts to use the innovation with related activities of colleagues to achieve a collective impact on clients within their common sphere of influence.	*5: Integration* State in which the preservice teacher use technology for teaching to make a collective impact of technology integration on student learning by allowing students to use technology collaboratively with others out of the classroom. For example: -The preservice teacher provides opportunities for or encourages students to use technology collaboratively with partnerships beyond the classroom (e.g., parents, professors, scientists, etc.) that promote their higher-level learning skills.
6: Renewal State in which the user reevaluates the quality of use of the innovation, seeks major modifications of or alternatives to present innovation to achieve increased impact on clients, examines new developments in the field, and explores new goals for self and the system.	*6: Renewal* State in which the preservice teacher reevaluates the quality of technology integration, seeks major modifications of or alternatives to achieve increased impact on students, examines new developments in the field, and explores new goals for self and the educational system. For example: -The preservice teacher makes efforts to have the learning settings seamlessly integrate with technology, in which students are engaged in student-centered, higher-order, and collaborative learning activities. Learning is impossible without the use of technology at this level.

Validity and Credibility

Strategies of audit trail, data triangulation, and colleague examination were applied to promote the validity and credibility of this study. First, audit trail was used to establish the rigor of the study. Merriam (1988) explained that “In order for an audit to take place, the investigator must describe in detail how data were collected, how categories were derived, and how decisions were made throughout the inquiry" (p. 172). This study elaborated the process of how this prototype of the TPACK-based ID model was developed by incorporating the suggestions from the previous prototype, how the design principles were transformed into practical activities, and how the collected data were analyzed by the coding scheme so as to allow interpretation of the participants' TPACK acquisition. Second, data triangulation was deployed to secure the research validity. Data triangulation refers to the use of multiple sources of data to verify the emerging findings (Merriam, 1995). In this study, the participants' learning process was recorded and evidenced in various types of data, including their discussion worksheets, lesson plans, digital artifacts, and teaching videos. In addition, the researcher, also the instructor, observed the participants in each class over the semester and took field observation notes that helped triangulate the data collected from the participants. Third, colleague examination was used as a confirmatory strategy. Colleague examination refers to "asking peers or colleagues to examine the data and to comment on the plausibility of the emerging findings" (Merriam, 1995, p. 54-55). The researcher consulted with the major professor regularly for two years to discuss research ideas, design of the study, the development and implementation of prototypes of models, the analysis of data, and the interpretation of findings. We had rich and deep discussion that ensured rigorous process to derive valid knowledge and findings.

Findings

In response to Research Question 1 with respect to the effects of the model, the findings below are described according to the three steps of Prototype II of the TPACK-based ID model.

Step 1—*Understand TPACK*

Two TPACK worksheets were used to help the participants build their knowledge base of TPACK in this step. The participants found 3-5 peers to discuss questions on TPACK Worksheet-1 and 2 (five groups were formed in each section of the course, M1-M5 in Section 1 and N1-N5 in Section 2).

TPACK Worksheet-1. In this worksheet, each group was required to discuss the definitions and create examples for TK, CK, and PK. All of the groups completed the worksheet in 8-12 minutes. During the discussion process, the groups actively searched for the provided online materials to respond to questions. The instructor-researcher walked around the class to see if any group had problems. No group asked questions or demonstrated difficulties in responding to the questions. At the end of the activity, groups shared their responses with the class by writing the group-created examples on the whiteboard. Their responses were mostly accurate. For instance, the examples of CK created by the groups included: proof of mathematics, literary interpretation, knowledge of procedures and theories, etc. There was even a group that provided examples involving their interpretation: CK refers to “An English teacher teaching about citations actually knows how to create proper citations”, and TK refers to “A physics teacher using Smartboard or Dabbleboard in order to portray accurate scales and vectors of different situations”. However, there were some minor aspects of their responses in need of correction. For example, one group thought that “a lesson plan” belongs to PK. The instructor explained that the response was too general because a lesson plan requires integrating PK and CK or PK, CK, and TK. Overall, groups’ learning process and responses to TPACK Worksheet-1 showed that their understanding of the meanings of TK, CK, and PK.

TPACK Worksheet-2. In this worksheet, groups started to discuss integrated knowledge of TPACK (e.g., TCK, TPK, PCK, and TPACK). They spent two class periods completing the two parts of the worksheet respectively (TPACK Worksheet-2 has two parts of TPACK-related questions that were designed based on the two videos presented two teaching examples).

TPACK Worksheet-2, first class period. Compared to TPACK Worksheet-1, groups demonstrated difficulties answering the questions regarding integrated knowledge. In the first class period, a video that demonstrates an effective TPACK teaching (as described in the “Procedures” section, this video was an example of teaching with effective TPACK integration) was presented for about 8 minutes, and then the groups spent 30 minutes working on the first part of TPACK Worksheet-2 (a few groups continued to work even after the class ended). During their discussion, the instructor walked around the class to get a sense of the groups' progresses and problems and to provide support. Groups had difficulties interpreting how the technologies used in the video represented the content (TCK) and facilitated students' learning (TPK). The instructor provided an explanation by comparing the good example shown in the video (e.g., visualizing cardinal directions in online maps) to traditional teaching methods (showing directions on a paper map) to indicate the difficulty in teaching if there is no support of technology. With support from the instructor, all the groups completed the first part of the worksheet, in which their explanations indicated how the technologies used in the good example helped students learn the content (see Table 3.4 for selected responses).

TPACK Worksheet-2, second class period. In the second class, the instructor demonstrated the non-example teaching video (as described in the "Procedures" section, this video was an example of teaching without effective TPACK integration) for 7-9 minutes, and then the groups used the rest of the class time, about 30 minutes, completing the second part of TPACK Worksheet-2. Groups demonstrated fewer difficulties responding to questions because the knowledge acquired from the first part of the worksheet could be applied to this activity. The analysis of the worksheet responses indicate that the groups' responses were based on the TPACK concepts but they were imprecise and/or superficial. Only three groups (M1, M4, & N5, 30% of the whole participating groups) provided responses to the TCK question considering content characteristics, and two groups (N3 & N5, 20% of the whole participating groups) provided responses to the TPK question considering students' learning. Taking the groups' responses to the TCK question as an example, as shown in Table 3.4, the response from Group 5 in Section 1 (M5) was imprecise in that the group did not consider critically the necessity of applying the technology (online games) to the specific content (living and non-living things). The responses from Group 3 (N3) and Group 4 (N4) in Section 2 were superficial in that they did not provide alternative methods to improve the non-example technology integration. Only a few groups (30% of the whole participating groups), such as Group 5 in Section 2 (N5), considered the relationship between the content and technology as shown in the following response: “Online games are helpful, but not necessary. For this topic, it might be more beneficial to actually go outside instead of using the [online] game”.

TPACK Worksheet-2 also asked the groups to compare the two teaching videos in terms of the quality of technology integration by giving scores (1 to 10, 10 being the highest) as well as rationale for their rating. The average score of Video 1 was 8.2 and that of Video 2 was 4.1, which indicated that groups could identify the quality of technology integration of the two examples. In the explanation, all the groups provided responses from the perspectives of students’ learning and content characteristics (TPACK) to acknowledge the better quality of Video 1. The last part of Table 3.4 shows the examples from the groups’ responses.

Comparing groups’ responses to the TPACK-related questions between Video 1 and Video 2, the groups accurately described how the technology used in Video 1 (the good example) supported students’ content learning. The goal of Step 1 was achieved in that the participants had a *basic* understanding of how a teacher integrated TPACK in teaching practice from the example video. However, groups demonstrated insufficient knowledge in evaluating the suitability or necessity of the applied technology in Video 2 (the non-example).

Table 3.4

Example Responses of Groups' Discussion on TPACK-Based Questions

TPACK-based Questions	Video 1 (The Example of Effective TPACK Integration)	Video 2 (Non-example of TPACK Integration)
TCK: Q1. How did the tool(s) represent/transform the content into forms that are comprehensible or that made it easier for learners to realize the content (Video 1)? Q2. Are the technological tool(s) unique, necessary, and helpful for that topic (Video 2)?	This tool [MapQuest and kid Pix] brings an abstract and spatial idea to life in video. This allows students to visualize the cardinal directions without a map. Once the students understand the directions in the real world, they will be able to apply them to a map more successfully. (M1) The technological tools were able to take the students on virtual field trips, which allowed them to see the content and visualize them. (N1)	-Yes, it allowed the class to interact and discuss characteristics of living and nonliving things in order to come to find the correct answer. (M5) - They [online games] are not necessary because there are many other mediums to explain this concept better. (N3) -They are unique and more engaging for the class as a whole but it is not necessary. I think it was [still] helpful for students. (N4)
TPK: What activities were the students engaged in when using technological tool(s)? (TPK)	Because 4th grade minds are thinking in such concrete ways, they cannot grasp such an abstract concept without visual cues like video...students are creating their own construct of the cardinal directions when they are using the interactive map for themselves. Instead of seeing the directions on a 2D map in a book, the students are engaged in an activity where there is a goal or destination. The students have to apply their knowledge of directions in order to maneuver their way through the map. (M1) Mapquest provides the students a map to read and [they] understand how to directionally get to a place. Students understand the concepts of NSEW [cardinal points] better when having to actually do hands-on activities. Because the students are using Mapquest to get to their destination, it makes them construct and organize the knowledge and concepts to achieve their goal of directing themselves using a map. (N2)	-The teacher could use more meaningful tools to teach the students that help the students grasp the concepts being taught. The tools that could be used to teach the subject should offer a better demonstration of living and non-living things. (M2) -It was meaningful because she [the teacher] taught it then immediately implemented it by showing them how to apply it. (M3) -The use of the computer between the student and their own desktop enhanced the lesson by being entertaining. (N4)

TPACK: Comparing the two teaching videos, in which one do you think that the technology better represented/transformed the content into forms that are comprehensible and that made it easier for learners to realize the content? Why?	The first video used technology when it was more necessary for her students. Cardinal directions are an abstract concept that would be difficult for the students to learn by traditional methods. Maps are better represented on a computer with technology because they allow students to visualize a large idea in a single space. The video on living/non-living things can be easily represented in real life because the students have dealt with these objects in their everyday lives. The students could better identify the differences between living and nonliving things by dealing with objects in the real world. (M1) We think the first video was [better] enhanced with technology. The second lesson would [have] been beneficial if the teacher incorporated hands-on activities or other engaging tasks. The first lesson was unique and enhanced because the teacher projected maps and pictures, and students could visualize material being presented. (N4)

*Five groups in Section 1 (M1-M5) and Section 2 (N1-N5) of the course

Step 2—*Engage in TPACK*

This step the participants produced 200 lesson plans, of which 190 lesson plans were individual-created (each 38 participant developed five lesson plans) and 10 lesson plans were group-created. To provide an organized and succinct view of the data, *quota sampling* (Castillo, 2009) was used in this step. Based on the LoU levels (see Table 3.3 for the level description) given to the first lesson plans that the participants developed (Lesson Plan 1), the participants were segmented into one of three performance groups—High (Level 3-*Mechanical use* or above), Middle (Level 2-*Preparation*), and Low (Level 1-*Orientation*). Then, five to six participants were selected from each of the performance groups. This segment allows the interpretation of the data in consideration of the participants' (initial) abilities. Table 3.5 summarized the LoU levels given to the individuals' and the groups' lesson plans created in Step 2. Letters A to F refer to the six participants selected from each of the performance groups, of which participants A, B, C were from Section 1 and participants D, E, F were from Section 2 of the course. Letters X1 to X5 refers to the five groups formed in class Section 1, and Y1-Y5 refers to the five groups formed in class Section 2.

Table 3.5

Lesson Plans Rated Using the LoU Framework

Participants / Project /Mode	Individuals																	Groups									
	High Performance						Middle Performance						Low Performance					X1	X2	X3	X4	X5	Y1	Y2	Y3	Y4	Y5
	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E										
Project 1 (Individual plan)																		N/A									
Lesson Plan 1	4b	3	3	4b	3	3	2	2	2	2	2	2	1	1	1	1	1										
Group Mode	3						2						1														
Project 2 (Group plan)	N/A																	1	1	3	3-4b	3	1	2	5	3	3
Lesson Plan 2																											
Project 3 (Individual plan)																		N/A									
Lesson Plan 3	3	4b	3	4b	3	1	2	2	3	2	1	3	1	1	1	2	1										
Lesson Plan 4	4b	3	3	3	4b	2	2	2	3	2	4b	3	3	1	2	1	2										
Lesson Plan 5	3	3	2	2	3	2	2	1	3	3	3	2	1	2	2	0	3										
Lesson Plan 6	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	1	2										
Individual Mode	3	3	2,3	2	3	2	2	2	3	2	N	2, 3	1	1	2	1	2										
Group Mode	3						2						1														

* A-F refers to six individual participants. A-C were from Section 1 and D-F were from Section 2 of the course.
* X1-X5 refers to the five groups in Section 1, and Y1-Y5 refers to the five groups in Section 2.
* Digital numbers refer to a level of LoU given to individually- or group- created lesson plans: Level 1-*Orentation*; Level 2-*Preparation*; Level 3-*Mechanical use*; and Level 4b-*Refinement.*

Project 1. Project 1 was an individually-created lesson plan (Lesson Plan 1). This was the participants' first exercise in designing a technology-integrated teaching activity. They were required to integrate one technological tool that they had learned from the course up to that point (e.g., choosing from Blogging tools, podcasting tools, Google Docs, the GLOBE Program, etc.). However, they were also encouraged to explore an additional set of technologies that were not covered in the class up to that point, choose one from that set, and integrate it with the required tool into the lesson plan.

The participants whose projects were rated at LoU Level 3 or higher were grouped into High Performance, in which the technology was used in student-centered ways (4b-*Refinement*) or to promote a higher-level of cognitive processing (3-*Mechanical use*). The participants whose projects were rated at Level 2 (*Preparation*) were grouped into Middle Performance, in which technology was used to support content understanding or a lower-level of cognitive processing. The participants whose projects were rated at Level 1 (*Orientation*) were grouped into Low Performance, in which technology was used to deliver teachers' lectures. Table 3.6 shows the examples of Lesson Plan 1 created by Participant A from each of the performance groups.

Table 3.6

Examples of Lesson Plan 1 Selected From the Three Performance Levels

Participants	Selected Lesson Plan 1	LoU Level
HA (High Performance group, Participant A)	I plan to teach eighth grade Visual Arts…Students will be using blogging to communicate the meaning behind their art work. They will also use blogging as an organizational source, allowing them to archive their work to refer back to later and trace their growth as an art student over the course of the semester… Blogging is also a tool for collaboration because students will use it to be able to comment on the blogs of their peers while they are defending their own work on their personal blogs… Power Point is to be used to display a combination of the artwork of the whole class. At the end of every project, students will each make a Power Point slide displaying their artwork.	4b (Refinement)
HC (High Performance group, Participant C)	I will create a lesson plan for my students to write a song about different elements from the periodic table… The students will work in groups to collaborate and then record their song. The way that I will use technology to teach this content is by allowing the students to study and explore the elements from WebElements… the students will individually explore the website learning about elements…then their group will be assigned a specific [element] group. By providing the technological tools the students would then create a podcast out of their recorded song. The podcast would then be posted online so others could find it and listen to it… They are responsible to create the lyrics and the tune and then record the song	3 (Mechanical use)

	together… I will get the recording equipment set up. I will help each group record their song and create the recording into a podcast.	
MA (Middle Performance group, Participant A)	I plan on introducing my lesson to my students by demonstrating how to use Mapquest [an online web mapping tool] and Google Maps. I will give them two different points on the map and show them how to put the information into the computer and how to interpret what they see on the map. If they need to get directions to a certain point, I will demonstrate how to use Mapquest and see the different turns it takes to get to their destination and the distances between each turn. Students will then be given a starting point and a destination and will then have to answer questions about distance and time.	2 (Preparation)
LA (Low Performance group, Participant A)	I think that Photo Story or iMovie would be a very beneficial tool to teach middle schoolers about track and field sports, which includes running and my experience... Because sports are so popular in our day, a movie would provide students with a visual of how my own experience as a runner looks like. I could show that video and the pictures in my class as an introduction to my class (and give them a URL to study from home). I believe this would be a beneficial way for students to learn about a personal story as well as get information about track and running	1 (Orientation)

As listed in Table 3.6, Participant A in the High Performance (HA) group designed a lesson plan in which students used blogging tools to organize, archive, and trace their own learning processes and used PowerPoint to illustrate learning outcomes. In HA's design, student-centered strategies were used and the teacher played the role of a facilitator (Level 4b-*Refienment*). In the lesson plan created by Participant A from the Middle Performance (MA) group, students used MapQuest to show their understanding of distances between two points (lower-level cognitive skills) after the teacher's demonstration (Level 2-*Preparation*). The lesson plan created by Participant A from the Low Performance group (LA) showed that technology (Photo Story) was mainly used by the teacher to support her lectures (presenting track and field sports), and students were not given opportunities to use technologies (Level 1-*Orientation*).

Project 2. In Project 2, the participants found two to four peers by themselves to collaboratively develop Lesson Plan 2, which integrated Photo Story. Five groups were formed in each section of the course (X1-X5 in Section 1 and Y1-Y5 in Section 2). Table 3.5 lists LoU level evaluation for each group's lesson plan. Three groups were rated at Level 1 (*Orientation*, X1, X2, & Y1), one group was rated at Level 2 (*Preparation*, Y2), four groups were rated at Level 3 (*Mechanical use,* X3, X5, Y4, & Y5), one group was rated at Level 3-4b (*Mechanical use* to *Refinement*, X4), and one group was rated at Level 5 (*Integration*, Y3).

Table 3.7 shows the sample lesson plans from Group 1 (X1), Group 3 (X3) and Group 4 (X4) in Section 1 and Group 3 (Y3) in Section 2 that were rated at Level 1, Level 3, Level 3-4b, and Level 5 respectively. The three groups whose lesson plans were rated at Level 1 (*Orientation*) tended to used Photo Story to present the content or support teachers' lectures. For example, as shown in Table 3.7, Group 1 in Section 1 (X1) used Photo Story to show students pictures regarding scientific landforms. The four groups whose lesson plans were rated at Level 3 (*Mechanical use*) attempted to have students actually create a slide show using Photo Story to demonstrate and reflect on their learning. For example, Group 3 in Section 1 (X3) required students to make a digital story after reading a novel to present the characters in the book, the themes, or any other topics. Group 4 in Section 1 (X4) that was rated at Level 3-4b (*Mechanical use* to *Refinement*) planned to videotape the gymnasts' actual performance of bar routines in order to help students solve *authentic problems* that gymnasts often confront (Level 4b-*Refinement*). However, the lesson plan was rated 3-4b because it was not beyond the description of Level 3 (*Mechanical use*), in which teacher-centered strategies dominated the learning process. The lesson plan from Group 3 in Section 2 (Y3) was rated at Level 5 (*Integration*) in that students' use of technology went beyond the classroom for authentic issues and had to collaborate with parents. For example, Y3 planned on having a Photo Story workshop for parents to teach them how to use Photo Story and then had parents work with their children to create a digital story that integrated school learning content into their real life surroundings.

Table 3.7

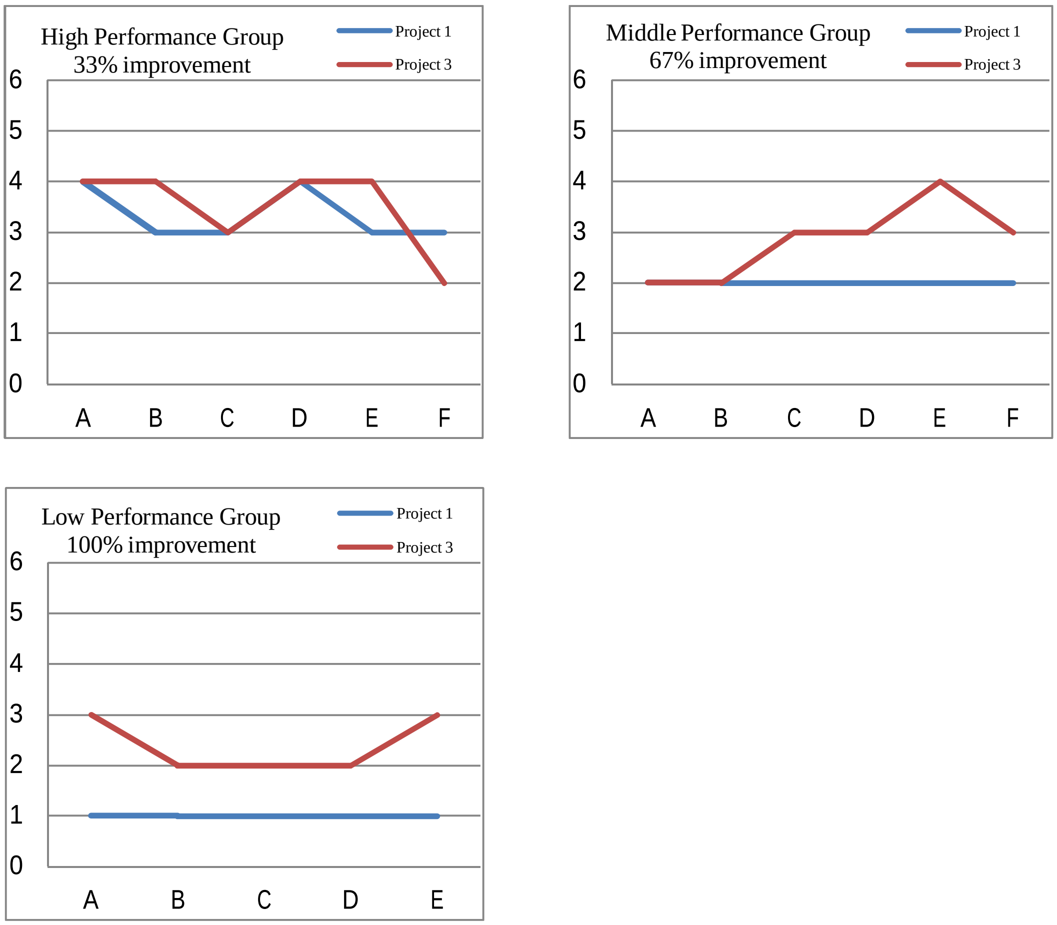
Selected Examples From Lesson Plan 2

Group	Selected Lesson Plan	LoU Level
X1 (Group 1 in Section 1)	I think that Photo Story or iMovie would be a very beneficial tool to teach middle schoolers about different landforms. Because we can only travel so much, a movie would provide students with a visual of what these different land forms look like. I could show these pictures to my class every day for a week (and give them a URL to study from home), and then show them the same pictures during the test. I believe this would be a beneficial way for students to learn the pictures associated with landforms, instead of merely learning a word.	1 (Orientation)
X3 (Group 3 in Section 1)	Topic: Novels in American Literature Subject: Book Reports Grade Level: 10^{th} Teaching Process: The students will be asked to read a novel of their choice (from a given list), and instead of relying on traditional methods such as essays, the students will be required to make their own Photo Story on a given topic. The topics can be about the characters of the book, the themes, or any other approved topic.	3 (Mechanical use)
X4 (Group 4 in Section 1)	Topic: Routines Subject: Gymnastics Grade Level: 7^{th} -10^{th} Teaching Process: 1) We can use iMovie to find YouTube clips of different skills. From there we can make a movie of the YouTube clips, and we can show the full movie to the gymnasts, so they can get new ideas of different skills and see how they are performed. 2) We can also use iMovie to put clips of our gymnasts actually performing their new routines into normal motion and then in slow motion. From there we can create a full length video and have a movie practice with our gymnasts. 3) We can then put the video into iMovie and have a movie day practice, showing the gymnasts what they're doing right and wrong in their routines.	3-4b (Mechanical use-Refinement)
Y3 (Group 3 in Section 2)	We plan on teaching Pre-K and the topic for this week is the letter R. We can show different video clips of the letter R and the associated words that start with R… We can also narrate the video to explain it in our own words. By using our own narration, we can get the students	5 (Integration)

	involved in the activities. For example, "Say the letter R." Show them a picture and say, "What do you think this is? Using Photo-story, they [students] can use it at home and actually get practice so that they are well-educated on the subjects taught in class… Also, they are learning how to narrate their own story. We can also let them narrate additional words that start with R for homework. This tool allows them to think critically about their surroundings…The children can go home and listen to these stories as bed time stories with their parents or they can listen and watch the videos for fun of their favorite videos. On top of that, I can also use photo-story to assign homework assignments that the children and their parents can do at home…Before sending home assignments, we plan on having a parent workshop to teach them how to use photo story.

Project 3. In Project 3, the participants used four technological tools to create four digital artifacts and four associated lesson plans (Lesson Plans 3 to 6). In Lesson Plan 3, the participants chose one tool among Photo Story, Slowmation, or Blogging tools. In Lesson Plans 4, 5, and 6, participants were required to integrate an image editing tool, a concept-mapping tool, and an online game, respectively. Table 3.5 shows the LoU levels given to the participants' four lesson plans in Project 3. Levels given to the four lesson plans in the High Performance group ranged from Level 1 (*Orientation*) to Level 4b (*Refinement*), while the mode of the group levels was Level 3 (*Mechanical use*). Levels given to the four lesson plans in the Middle Performance group ranged from Level 1 to Level 4b, while the mode of the group levels was Level 2 (*Preparation*). Levels given to the four lesson plans in the Low Performance group ranged from Level 0 (*nonuse*) to Level 3, while the mode of the group levels was Level 1.

The levels given to the four lesson plans in Project 3 were also compared to the levels given to Lesson Plan 1 in Project 1 in order to see if there was any improvement in the quality of their work. Figure 3.3 illustrates the changes in the levels of technology integration comparing Project 1 to Project 3 among the three performance groups.



* A-F refers to Participant A to Participant F.

* 0-6 refers to the levels of LoU. Level 1-*Orentation*; Level 2-*Preparation*; Level 3-*Mechanical use*; and Level 4(b)-*Refinement.*

Figure 3.3. Changes of levels of technology integration in comparison of Project 1 to Project 3

As shown in Figure 3.3, in the High Performance group, Participants A, C, and D (HA, HC, and HD) maintained their performance in that the *highest* level given to their Project 3 was the same as that given to their Project 1 (e.g., HA's Lesson Plan 4 was rated at Level 4b, the same level as her Project 1). Participant B (HB) and Participant E (HE) improved their performance in that the *highest* level given to their Project 3 was Level 4b, while their Project 1 was rated at Level 3. However, the performance of Participant F (HF) was worse (Level 3 in Project 1 compared to Level 2 in Project 3). Overall, five out of six participants in the High Performance group either improved (two participants, 33%) or maintained (three participants, 50%) the level of technology integration. In the Middle Performance group, Participants A and B (HA & HB) maintained their performance in that the *highest* level given to their lesson plans in Project 3 was Level 2, which was the same level given to their Project 1. Participants C, D, E, and F (MC, MD, ME, MF) improved their performance in that the *highest* levels given to their lesson plans were Level 3 or Level 4b (compared to the assignment of Level 2 to their Project 1). Overall, four out of six participants in the Middle Performance group improved the level of technology integration (67%). In the Low Performance group, all five participants improved the level of technology integration (100%). The *highest* levels given to the five participants' lesson plans were Level 3 (LA & LE) or Level 2 (LB, LC, & LD), while the level given to their Project 1 was Level 1.

Another change was that seven out of the 17 participants (HA, HB, HD, HE, MA, MC, MF, 40%) showed a growth in their level of accepting challenges from technological tools from Lesson Plan 3 to Lesson Plan 6. In other words, they selected content to maximize the affordance of given technologies even when the lesson design to teach the selected content was more complex and difficult. Table 3.8 lists sample lessons illustrating the growth in welcoming challenges.

Table 3.8

Lesson Plans 3-6 of Participant F in the Middle Performance Group

Topic: Colors Subject: Visual Arts Grade level: 4-5th Grade		LoU Level
Lesson Plan 3 (Photo Story)	Objectives: - Use Digital Storytelling: to teach students about the different types of colors. Teaching resources/materials: - Website: http://www.colourtherapyhealing.com/colour/ Teaching process: - Ask students what their favorite color is? - First, have students watch the digital story [created by the teacher]. - Second, have students create a digital story about the use of color in their daily lives.	3 (Mechanical use)
Lesson Plan 4 (images editing tool)	Objectives: - Use Images: teach the students how to edit images in Picasa and how to make something more visually appealing for others Teaching resources/materials: - Website: http://picasa.google.com/ Teaching process: - First, have students collect five colorful photographs from their daily lives. - Next, have the students log on to Picasa and let them explore the different ways to manipulate images to make them more visually appealing.	3 (Mechanic al use)
Lesson Plan 5 (concept mapping tool)	Objectives: - Use Brainstorming: teach the four categories of color (primary, secondary, subtractive, and tertiary) and the colors that fall under each category. Teaching resources/materials: - Website: http://www.colourtherapyhealing.com/colour/ - https://bubbl.us/ Teaching process: - First, ask the students if they have ever heard of any of these categories; if so, what have they heard? - Second, separate the class into four groups - Then, have them refer back to the website to identify which color falls under which category. - Finally, have them create a brainstorming map for their specific category, linking it to the different colors that make up that category of colors.	2 (Preparatio n)

Lesson Plan 6 (online game)	Objectives: - Use these Puzzles and Games: to let students explore the different aspects of color Teaching resources/materials: - Website: http://www.colourtherapyhealing.com/colour/colour_fun/ Teaching process: - First, break the class into seven groups and allow the groups to explore the different games available on the Color Therapy Healing website. - Next, after they have finished, ask the students what they learned about color from those games.	2 (Preparation)

It is worth noting that all 17 Lesson Plans 6 (integrating online games) were rated as LoU level 2. Two similarities were found among their lesson plans. First, they used online games to assess students' lower-level cognitive skills regarding the comprehension of the content. Second, 15 participants designed their lesson to use ready-made online games; only two participants used online game templates to create games in order to meet specific needs in their lesson contexts. These two findings indicate that technology integration of 88% of the participants was done more from the perspective of teachers' efficiency and convenience than from that of students' learning.

Step 3—*Practice TPACK*

In this step, the participants themselves found 2-4 peers to form a group to work on the final project—developing a technology-integrated lesson plan and implementing a section of the plan in the class for 30 minutes. Five groups were formed in both class sections (U1-U5 in Section 1 and V1-V5 in Section 2). All ten groups integrated various technologies that they had learned in the class to present the learning content (TCK), such as Photo Story, image editing tools, concept maps, and online games. They also explored and integrated online videos, animation tools, and digital photos to support content instruction. Table 3.9 shows a sample lesson plan that integrated various technologies.

Table 3.9

The Final Lesson Plan From Group 2 in Section 1 (U2)

Lesson Plan	Technology Used
Topic: The Water Cycle **Including subject(s): Evaporation, Precipitation, Condensation** **Grade level: 2-3** **Objectives:** Give our students a deep understanding of the three steps of the water cycle. We want them to know how the three portions of the water cycle work together and how it can apply to our lives. We want our students to have a hands-on experience with the water cycle so that they can think and discuss the portions of the water cycle in a critical way.	
Teaching process (30-35 minutes): -Concept Map: We will use the concept map to provide a general overview of what students are going to learn in class today. The concept map outlines the basic ideas of the water cycle.	concept map
-Lesson Video: We will use iMovie to help us teach our lesson about Evaporation, Condensation, and Precipitation. The video gives them [students] a chance to visualize and see what we are teaching and they are able to look back at these three main principles of our subject while they are back at home.	group-created video
-Images: [Teachers will] edit 8-10 images to show the dynamics and functions of the water cycle. These images should represent Evaporation, Condensation, and Precipitation of all forms and truly attempt to stimulate the students learning with this visual tool.	images editing tools
-Experiment Video: We used iMovie to give the students an example of science in their own house. The students are able to use this video and try this experiment while they are at home along with being able to better understand the concept that we are teaching in class.	group-created video
-Class Experiment: We will use the knowledge that the students have gained about the water cycle and see how it plays out in an experiment. This experiment will mimic the water cycle for the students on a level that they can see and create themselves. We will use an online guide that will step the students through the experiment.	
-Wordle: Wordle will be used as a review at the conclusion of the lesson. Each student will be asked to brainstorm one word that they associate with the water cycle. As a class, we will call them out and type them into the template that can be found at www.wordle.net. After we have typed them in, we will create a “wordle” and keep it to remember all of the things that we have learned.	word clouds generating tool
-Game: To test the students’ knowledge of the water cycle, we will be playing a jeopardy game. This allows the students to collaborate together to work on applying the knowledge that we have gained in class about the different parts of the water cycle.	group-created PowerPoint game

The groups' lesson plans were evaluated using LoU. Two groups' lesson plans (U5 & V2) were rated at Level 3 (*Mechanical use*), and the rest of the groups were rated at Level 2 (*Preparation*). The groups that were rated at Level 3 used technology to support students' higher-order thinking skills. For example, Group 5 in Section 1 (U5) taught the topic "Five Senses", in which the students listened to different digital sounds and *analyzed* the sounds so as to determine what the sounds were. The groups that were rated at Level 2 mainly used technology to support lower levers of content understanding. For example, six groups used concept maps to give students an overview of the upcoming learning content (U1, U2, U3, U4, V2, & V3), and three groups asked students to fill in a concept map with blank boxes after the teaching to assess their comprehension of the content (U5, V3, & V5). They also created videos to demonstrate an experiment regarding water evaporation and condensation (U2), explain concepts of the learning content (U2, U3, U4, U5, & V1), or create a video letter for parents (V5).

Compared to the lesson plans created in Step 2 (*Engage in TPACK*), student-centered strategies of technology integration decreased in Step 3 (*Practice TPACK*). For example, in Step 2, 6.2% lesson plans from the High and Middle Performance groups were rated at Level 4b (*Refinement*) that included student-centered activities (e.g., each student created a Blog to post an image with description each day to document and reflect on daily life). However, in Step 3, ten groups' technology applications were teacher-centered. Their learning of TPACK in Step 2 was not used in Step 3 when they had to *implement* the lesson plan in the class.

Summary of Findings

In response to Research Question One, the effects of Prototype II of the TPACK-based ID model on improving preservice teachers' TPACK are summarized in terms of the three steps of the model as follows:

1. Step 1 (*Understand TPACK*): Opportunities for the participants to discuss TPACK and view, assess, and compare TPACK integration teaching examples facilitated their basic understanding of TPACK. However, the participants were not able to evaluate and provide specific suggestions with regard to the non-TPACK example.
2. Step 2 (*Engage in TPACK*): LoU levels were improved from the initial lesson plans (Project 1) to the final lesson plans (Project 3); 33% improvement occurred in the High Performance group, 67% improvement occurred in the Middle Performance group, and 100% improvement occurred in the Low Performance groups. The highest levels given to Project 1 among the High, Middle, and Low Performance groups were Level 4b (*Refinement*), Level 2 (*Preparation*), and Level 1 (*Orientation*), while the highest levels given to Project 3 among the three performance groups were Level 4b (*Refinement*), Level 4b, and Level 3 (*Mechanical use*). This improvement indicates that the participants' TPACK was improved.
3. Step 3 (*Practice TPACK*): Two groups' implementations of the final lesson plans were rated at Level 3 (*Mechanical use*), and the remaining eight groups were rated at Level 2 (*Preparation*), indicating 100% teacher-centered strategies of technology application. The participants' understanding of student-centered strategies of technology application (LoU Level 4 and above) in Step 2 (Project 3 had 7% of student-centered lesson plans) was not utilized in actual teaching in Step 3.

Discussion

Prototype II is a revision of Prototype I of a TPACK-based ID model that involved much more active application of TPACK. In a sense, this is consistent with Merrill's First Principles of Instruction which he has summarized on many occasions publicly with the statement that people learn what they do (Merrill, 2002, 2009). Prototype II involved a lot more doing TPACK-related activities than did Prototype I. The findings indicated that the preservice teachers' TPACK was enhanced through the activities of discussing the meanings and examples of TPACK actively (Step 1—*Understand TPACK*) and designing several technology-integrated lesson plans (Step 2—*Engage in TPACK*). However, their TPACK was not fully utilized in the context of teaching in Step 3 (*Practice TPACK*).

In terms of the design principles as described earlier (see the "Design Principles" section), the focus of Prototype II was on providing pedagogy-enhanced activities to improve preservice teachers' teaching-related knowledge so as to facilitate their learning of TPACK. The findings showed that Principle 2 (relating to Step 1) and Principle 3 (relating to Step 2) were effective in that preservice teachers' TPACK was improved. However, there are still several aspects in need of revision in the three steps so as to enhance preservice teachers' TPACK and, ultimately, optimize the effectiveness of the TPACK-based ID model.

First, in Step 1, the preservice teachers could differentiate the quality of technology integration between a TPACK-integration teaching example and non-example easily. However, when they were asked to give detailed explanations of a TPACK example and non-example based on TPACK concepts, their descriptions of the TPACK example were more detailed and accurate than those of the non-example. They may have lacked the ability to analyze critically and give constructive suggestions for the non-example. This finding seems to be consistent with the principles of cognitive processing because *evaluation* requires higher-order skills than does *comprehension* (Bloom, 1956). For the preservice teachers, *comprehending* that the TPACK example shows a more effective technology integration practice than the non-example may have been easier than *evaluating* specific components of each example. Although this study showed that group discussions of teaching examples helped preservice teachers learn TPACK, more improvements may have been observed if Prototype II of the TPACK-based ID model had included an element guiding the instructor in supporting preservice teachers to effectively evaluate technology integration practices.

Second, in Step 2 (*Engage in TPACK*), LoU levels were improved among all performance groups comparing each individual's initial lesson plan (Lesson Plan 1 in Project 1) to one of the four final lesson plans (in Project 3) that was rated at the *highest* LoU level. In the High Performance group, two (out of six) preservice teachers' lesson plans were rated at Level 4b (*Refinement*) in Project 1, while four (out of six) preservice teachers' lesson plans were rated at Level 4b in Project 3 (33% improvement). In the Middle Performance group, all six (out of six) preservice teachers' lesson plans were rated at Level 2 (*Preparation*) in Project 1, while four (out of six) preservice teachers' lesson plans were rated at either Levels 3 (*Mechanical use*) or 4b (*Refinement*) in Project 3 (67% improvement). In the Low Performance group, five (out of five) preservice teachers' lesson plans were rated at Level 1 (*Orientation*) in Project 1, while all five (out of five) preservice teachers' lesson plans were rated at either Levels 3 (*Mechanical use*) or 2 (*Preparation*) in Project 3 (100% improvement). The percentages indicated that the preservice teachers' TPACK was improved by designing lesson plans (in Project 3) that better integrated technology than their initial lesson plans (in Project 1).

Third, however, in Step 2 (*Engage in TPACK*) and Step 3 (*Practice TPACK*), the preservice teachers applied technologies mostly in teacher-centered ways. Among the 68 lesson plans developed in Project 3 of Step 2, only five lesson plans (7%) were rated at Level 4b (including student-centered strategies), which means that about 93% of the lesson plans were teacher-centered. In Step 3, no student-centered strategies (0%) were found in the 10 groups' lesson implementation in that their lesson plans were rated either at Level 2 (*Preparation*) or Level 3 (*Mechanical use*). This implied that the five individuals whose plans were rated at Level 4b in Step 2 did not demonstrate influence on the group work in Step 3. It is also possible that the preservice teachers thought of lesson implementation as presentation, so their teaching resembled giving lectures rather than interaction with students. Although findings showed that preservice teachers demonstrated improvement in their lesson plans at the level of LoU in Step 2, more improvements may have occurred in Step 2 and Step 3 if this study had included a component to teach preservice teachers student-centered strategies for technology integration. To further improve preservice teachers' TPACK, future research should consider that preservice teachers' understanding of the importance of active interaction between students and technology is critical to students' learning results.

Re-design of the Model

In response to Research Question Two, several aspects of the model should be improved so as to advance preservice teachers' TPACK and, ultimately, provide an effective TPACK-based ID model for teacher education. Step 1 (*Understand TPACK*) should include a component having the instructor provide more effective support to help preservice teachers evaluate the given examples. For example, the instructor can ask guiding questions to promote preservice teachers' critical thinking and use classroom assessment techniques (Angelo, 1995) to require them to write responses to the questions, and from the responses the instructor can select some for the next class meeting for discussion and elaboration (Maudsley & Strivens, 2000). The effective support can facilitate preservice teachers more accurate evaluation of both good and not-good technology-integrated teaching examples.

Second, in Step 2 (*Engage in TPACK*) and Step 3 (*Practice TPACK*), the technologies that the preservice teachers integrated into their lessons were applied in more teacher-centered ways than student-centered ways. The model should be revised to include components aiming to help preservice teachers understand the importance of student-centered strategies and possess the ability to practice the strategies. Preservice teachers should understand that student-centered technology application encourages students to discover, manipulate, and investigate, by which students have opportunities “to seek rather than to comply, to experiment rather than to accept, to evaluate rather than to accumulate, and to interpret rather than to adopt” (Hannafin & Land, 1997, p. 175). Third, if preservice teachers are grouped according to subject areas, preservice teachers may have more opportunities to discuss with peers suitable methods of applying technology in consideration of the characteristics of content.

Limitations of the Study and Future Research Suggestions

There are several limitations in the following aspects of this study should be addressed: the sampling method, data analysis methods, the design of the model, and the validly. First, quota sampling was used to segment and select samples based on the study needs instead of random selection (Castillo, 2009). However, this may have resulted in sampling biases.

Second, Prototype II attempted to improve preservice teachers’ teaching-related knowledge by having them discussing TPACK teaching examples actively (Step 1—*Understand TPACK*). In this step, the instructor walked around the classroom and provided explanation to facilitate groups’ discussion. However, it was possible that the instructor’s engagement was a disruption rather than a help for groups. It was also likely that the instructor’s explanations could only partially answer questions that the groups had. Thus, more systematic support (e.g., guiding questions or written feedback) from the instructor should be designed so as to effectively scaffold preservice teachers' TPACK building. Prototype II also had preservice teachers design several technology-integrated lesson plans to improve their teaching-related knowledge (Step 2—*Engage in TPACK*). However, this model did not emphasize student-centered strategies of technology application (LoU Level 4 and above), which could explain why the participants' lesson plans were mostly rated at Level 2 (*Preparation*) or Level 3 (*Mechanical use*) in Step 2 (*Engage in TPACK*) and Step 3 (*Practice TPACK*). The preservice teachers may have practiced teaching in a teacher-centered manner because their students were also classmates. Future research should enhance preservice teachers' teaching-related knowledge specifically about teacher-centered and student-centered strategies, so as to help them practice technology integration based on students' needs.

Third, the validity of the model should be improved. The model was implemented only in a technology course for which the researcher also served as the instructor. It was likely that the interpretation of the data interweaved the views of an instructor and a researcher, and the researcher might incorporate the instructor's personal teaching beliefs. As a result of this limitation, Design Principle 1 (Explicit and systematic procedures) could not be empirically examined because the researcher was the only practitioner. In addition, this study only had one colleague as the data reviewer. If more reviewers were involved, the objectivity and validity of finding interpretation might have been advanced. Future research should implement the model in diverse contexts, have different instructors to carry out, and include more validation strategies (e.g., multi-peers of peer review and member checking) to increase the validity of the model.

Conclusion

This study is the second prototype (Prototype II) of the design-based research to develop a TPACK-based ID model for teacher training programs to improve preservice teachers' TPACK in a multidisciplinary technology integration course. The design principles of this prototype focus on improving preservice teachers' pedagogy-related knowledge so as to facilitate their TPACK acquisition. The principles were transformed into practical activities (i.e., the three steps in the model) by engaging preservice teachers in group discussions, comparing teaching examples, and developing and implementing technology-integrated lesson plans. The results showed that preservice teachers' TPACK was improved (in Steps 1 and 2). However, when they actually used their TPACK in teaching (Step 3), technologies were used more in teacher-centered ways than student-centered ways.

Findings of this prototype inform the development of the next prototype (Prototype III) of an effective TPACK-based ID model. The implementation of the model improved the preservice teachers' TPACK by providing practical activities to enhance their teaching-related knowledge. The effective components of the model will be retained in the next prototype. Limitations were also found and revisions are suggested, which serve as vital information for the next prototype as well as future research to explore the optimal solutions for preservice teachers' TPACK acquisition. The ultimate goal of this design-based research is to offer an effective TPACK-based ID model for multidisciplinary technology-integrated courses to help preservice teaches practice effective technology integration for student learning.

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CHAPTER 4

THE THIRD PROTOTYPE OF THE DEVELOPMENT OF A TPACK-BASED INSTRUCTIONAL DESIGN MODEL: AN IMPLEMENTATION STUDY IN A TECHNOLOGY INTEGRATION COURSE[1]

[1] Lee, C. J. & Kim, C. A modified version of this chapter will be submitted to *Teaching and Teacher Education.*

Abstract

Prototype III of the Technological Pedagogical Content Knowledge (TPACK) based instructional design (ID) model has been developed based on the findings from the implementation study of Prototype II. The Prototype III model was applied in a technology integration course with seventeen preservice teachers who had a variety of subject area concentrations. A case study approach was used in the implementation study of Prototype III. Data included group discussion worksheets, technology-integrated lesson plans and relevant technological artifacts, videos recorded of lesson plans implementations, and the researcher's field observation notes. The results revealed the following: (a) preservice teachers' basic understanding of TPACK was built by active discussions that connected teaching examples to TPACK and through support and explicit feedback from the instructor, (b) preservice teachers' understanding of TPACK was advanced after engaging in student-centered, technology-integrated activities, and (c) preservice teachers applied their understanding of TPACK to practice by developing and implementing lesson plans that incorporated student-centered strategies and higher-order thinking activities. Suggestions and future research possibilities are also discussed.

Keywords: technology integration, TPACK, instructional design model, preservice teacher education, learning by design

The Third Prototype of the Development of a TPACK-Based Instructional Design Model: An Implementation Study in a Technology Integration Course

This study presents Prototype III of a design-based research effort to develop and examine a TPACK-based instructional design (ID) model for multidisciplinary technology-integration courses to improve preservice teachers' TPACK (Technological Pedagogical Content Knowledge). Two previous prototypes of the TPACK-based ID models (Prototypes I & II) have been implemented in technology-integration courses in which preservice teachers were from diverse majors (subject areas of specialization). Each implementation study of the prototypes informed the revision process in an effort to progressively improve the ID model being used to develop preservice teacher TPACK. Findings from Prototype II included the following: (a) preservice teachers built a basic understanding of TPACK by actively discussing the definitions and meanings of TPACK and by evaluating TPACK teaching examples, (b) developing several technology-integrated lesson plans improved preservice teachers' TPACK understanding and teaching-related knowledge, and (c) preservice teachers' technology application was more teacher-centered than student-centered in the *development* (93% vs. 7%) and *implementation* (0% vs. 100%) of lesson plans. Suggestions from Prototype II implementation study included the following: (a) provide immediate support to preservice teachers when they evaluate technology-integrated teaching examples and give explicit feedback on their responses, (b) improve preservice teachers' understanding (knowledge) of student-centered technology application, and (c) help preservice teachers apply their understanding (knowledge) of student-centered technology application to teaching practice.

The goal of this research is to systematically improve preservice teachers' knowledge and skills with regard to TPACK. The general objective of the series of prototypes and studies is to develop a robust ID model to achieve the goal. The specific objective of this study was to develop, implement, and examine Prototype III of the TPACK-based ID model so as to provide data and information to guide future efforts.

Theoretical Framework

This study is the third round (Prototype III) of the development and implementation of a TPACK-based ID model. Prototype III, as well as the previous two prototypes, was grounded in the following theoretical frameworks: (a) design-based research (Amiel & Reeves, 2008; DBR Collective, 2003; Reeves, 2006; Van den Akker, Gravemeijer, McKenney, Nieveen, 2006), (b) TPACK (Mishra & Koehler, 2006), (c) the *Learning by Design* approach (Kalantzis & Cope, 2005), and (d) instructional design models (Angeli & Valanides, 2005; Gagné, Wager, Golas, & Keller, 2005; Gustafson & Branch, 2002b).

Design-Based Research

Design-based research (DBR) is a methodology that helps researchers explore the optimal solutions for complex problems in educational settings through iterative design, development, and evaluation of interventions so as to generate knowledge about the characteristics of the interventions (DBR Collective, 2003; Reeves, 2006). Applying DBR, three prototypes (interventions) of a TPACK-based ID model were developed, revised, and examined consecutively in order to develop an effective model that can be used in multidisciplinary technology integration courses to improve preservice teachers' TPACK.

TPACK

Mishra and Koehler (2006) proposed the TPACK framework to describe the complex interplay between teachers' knowledge of content, pedagogy, and technology. The interaction of the three knowledge bases comprise seven areas of knowledge: (i) content knowledge (CK), (ii) pedagogical knowledge (PK), (iii) technological knowledge (TK), (iv) pedagogical content knowledge (PCK), (v) technological content knowledge (TCK), (vi) technological pedagogical knowledge (TPK), and (vii) technological pedagogical content knowledge (TPCK changed to TPACK, Thompson & Mishra, 2007). Mishra and Koehler noted that a teacher's professed knowledge of technology integration is the understanding of the complex interrelationships of the three knowledge bases instead of the consideration of them in isolation. From a TPACK perspective, there are not distinctive knowledge areas within TPACK. However, from a developmental perspective, these distinctive areas are useful in identifying where there are TPACK deficiencies and what might then be integrated into preservice teacher preparation to address those deficiencies.

TPACK is a theoretical concept that renders a promising framework for teacher education to improve teachers' technology integration. There have been some studies that provided practical strategies to carry out TPACK (e.g., Jang & Chen, 2010; Jimoyiannis, 2010; Polly, McGee, & Sullivan, 2010). However, these studies mostly focused on specific subjects (e.g., earth science or 8^{th} grade algebra). Since some teacher training programs provide technology integration courses that are not connected to specific subjects (National Center for Education Statistics, 2008), there is a need to provide multidisciplinary strategies for TPACK improvement in these preservice teacher preparation educational settings that involve teachers with different subject area or discipline concentrations.

The *Learning by Design* Approach

Technology is no longer the exclusive domain of education, and digital artifacts affect students' formal learning in the classroom. As stated by Kalantzis and Cope (2005):

> The new information and communications technologies and globalization have brought much more diversity to people's lives and the way they work and relate to each other. Classrooms are thus filled with learners whose informal learning resources and life experiences are extremely varied. How do we recognize these diverse experiences and build on them to create the best learning outcomes for our students? (p. ix)

Kalantzis and Cope discussed the L*earning by Design* approach and asserted that the approach is a promising teaching method to advance teachers' expertise and meet students' learning needs in the digital era (2005):

> The *Learning by Design* tools are based on a philosophy of teaching and learning that values a variety of active ways of knowing. Teaching that harnesses diversity and leads to learner transformation involves a number of **knowledge processes** that need to be made explicit and part of a teacher's pedagogical repertoire. (p. X)

The *Learning by Design* approach encourages teachers to take the responsibility of designing learning activities and materials for students' learning needs (Goodyear, 2001; Kalantzis & Cope, 2005; Kali, Levin-Peled, & Dori, 2009; Yoon, Ho, & Hedberg, 2005). This approach has been suggested by studies because it has the potential to provide innovative methods for student learning, improve teachers' professed knowledge, increase collaboration among teachers, and respond to the needs of future workplaces (Bers, Ponte, Juelich, Viera, & Schenker, 2002; Güler & Altun, 2010; Hjalmarson & Diefes-Dux, 2008; Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007). Drawing on the advantages of the *Learning by Design* approach, this study integrated the approach into the development of the model so as to improve preservice teachers' TPACK thorough active designing.

Instructional Design Models

Instructional design refers to "the systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation" (Smith & Ragan, 1999, p. 2). A variety of instructional design (ID) models has been proposed, many of which share five major activities referred to as ADDIE (analysis, design, development, implementation, and evaluation) (Branch, 2009). Gustafson and Branch (2002a) defined ADDIE as:

> (1) analysis of the setting and learner needs, (2) design of a set of specifications for an effective, efficient, and relevant learner environment, (3) development of all learner and management materials, (4) implementation of the resulting instruction, and (5) both formative and summative evaluations of the results of the development. (p.xiv)

Research in teacher education has drawn on the elements of the ADDIE paradigm to improve teachers' technology integration by developing ID models (Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010). For example, Jang and Chen proposed the COPR (standing for *C*omprehension, *O*bservation, *P*ractice, and *R*eflection) model to improve preservice science teachers' TPACK. However, current ID models designed to promote teachers' technology integration were mostly implemented or evaluated in specific subject or methodology courses. To fill the research gap, this study utilized the ADDIE paradigm to develop a TPACK-based ID model that can be applied to multidisciplinary technology integration contexts.

To make the teaching process in the ID model more effective and suitable for teacher training, this study drew on First Principles of Instruction (Merrill, 2002, 2009, 2012), which comprises five principles: (a) engaging learners in *a problem-centered* environment that requires them to solve a series of increasingly complex real-world tasks, (b) *activating* or recalling learners' previous experience, (c) *demonstrating* new knowledge and skills to learners in the setting of real-world tasks (*show me*), (d) asking learners to *apply* new knowledge to real world tasks along with providing appropriate feedback, instruction, and correction (*let me*), and (e) encouraging learners to *integrate* the new knowledge or skills into their lives (*watch me*).

Design Principles and the Revised Model

Design Principles

The second study that implemented the Prototype II of the TPACK-based ID model suggested the following revisions for the development of Prototype III: (a) preservice teachers receive support and feedback from the instructor when they discuss the quality of technology-integrated teaching examples with regard to TPACK, (b) preservice teachers should understand student-centered strategies for technology application, and (c) preservice teachers should learn to apply student-centered strategies to technology-integrated teaching practice. These suggestions led to revisions in design principles for the Prototype III model. Table 4.1 shows the comparison of the design principles of Prototypes II and III.

Table 4.1

Design Principle Changes in the TPACK-based ID Model

Design Principles of Prototype II		Design Principles of Prototype III
Principle1. Explicit and systematic procedures: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.	No change	**Principle 1. Explicit and systematic procedures**: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.
Principle 2.Understand TPACK: Preservice teachers' discussion of definitions, creation of examples, and comparison of teaching examples regarding TPACK can enhance understanding of the domains of TPACK.	Include instructor's active support during students' evaluation of technology-integrated teaching examples	**Principle 2. Understand TPACK:** Preservice teachers' discussion of TPACK and evaluation of technology-integrated teaching examples relevant to previous learning experience with the instructor's active support can enhance understanding of TPACK.
	Include the changes to (a) support understanding of student-centered technology technology application, and (b) transfer the understanding to teaching practice (a)	**Principle 3. Experience TPACK:** Opportunities for preservice teachers to experience student-centered, technology-integrated activities can facilitate the understanding of student-centered technology application.
Principle 3. Engage in TPACK: Opportunities for preservice teachers to develop, discuss, and revise a lesson plan for each of the technological tools can enhance the connection of technology to a specific subject and pedagogy. **Principle 4.Practice TPACK: Integrating technological tools to design a learning activity:** Opportunities to integrate several technologies to develop a lesson plan and opportunities to implement, reflect, and revise the	(b)	**Principle 4. Practice TPACK:** Opportunities for preservice teachers to design, gain feedback on, reflect on, revise, and implement student-centered, technology-integrated lesson plans can enhance the understanding as well as the practice of student-centered technology application.

lesson plan help transfer knowledge to practice.	

As shown in Table 4.1, Principle 1 was maintained in both prototypes since the findings of Prototype II did not indicate a need to change the principle. In accordance with Principle 2, the new principle kept the component from Prototype II: preservice teachers should actively discuss and explore the meanings and definitions of TPACK. However, Principle 2 included a new component: the instructor provides immediate support to preservice teachers when they discuss technology-integrated teaching examples that are relevant to their past learning experience and gives explicit feedback on their responses. The new component drew on Merrill's (2002, 2009, 2012) principle of *activation* by connecting TPACK (new knowledge) to preservice teachers' previous learning experience. Principle 2 aims at building preservice teachers' knowledge base of TPACK so as to help them evaluate the quality of technology integration effectively and facilitate their learning in the next more complex activities.

Principles 3 was revised based on the suggestion that preservice teachers should understand student-centered strategies for technology application. In this study, *student-centered strategies for technology application* refers to the pedagogical approach that the structuring of technology-integrated teaching activities is based on students' needs, interest, abilities, and the placing of the teacher as a facilitator. Students are given opportunities to use technology to "actively engage in and direct their learning process, set expectations and carefully select information they consider useful" (Motschnig-Pitrik & Holzinger, p. 164). Principle 3 provides preservice teachers with opportunities to experience student-centered, technology-integrated activities, which is consistent with Merrill's principle of *demonstration (show me),* stating that learners' new learning (e.g., preservice teachers' TPACK learning) can be enhanced by observing the instructor's demonstration.

Principle 4 of Prototype III integrated the components of Principles 3 and Principle 4 from Prototype II—preservice teachers design technology-integrated lesson plans (*develop*, *gain feedback, reflect on,* and *revise* lesson plans) and *implement* the lesson plans in the class as if they were real teachers. However, Principle 4 was also revised to include a new component: the understanding of student-centered strategies should be applied to the development and implementation of technology-integration lesson plans. The two main activities in Principle 4 are consistent with Merrill's principles of *application* and *integration,* respectively, by which preservice teachers are required to apply TPACK (new knowledge) to develop student-centered, technology-integrated lesson plans (*application*) and teach the lesson plans in the class (*integration*).

Overall, the revised design principles of Prototype III engage preservice teachers in *problem-centered* learning activities (Merrill, 2002, 2009, 2012) in which they learn from solving tasks ranging from simple (e.g., discussing meanings of TPACK) to difficult (e.g., developing and teaching student-centered, technology-integrated lesson plans) that can progressively enhance their TPACK.

The Revised Model (Prototype III**)**

Based on the revised design principles, Prototype III of the TPACK-based ID model was proposed as shown in Figure 4.1.

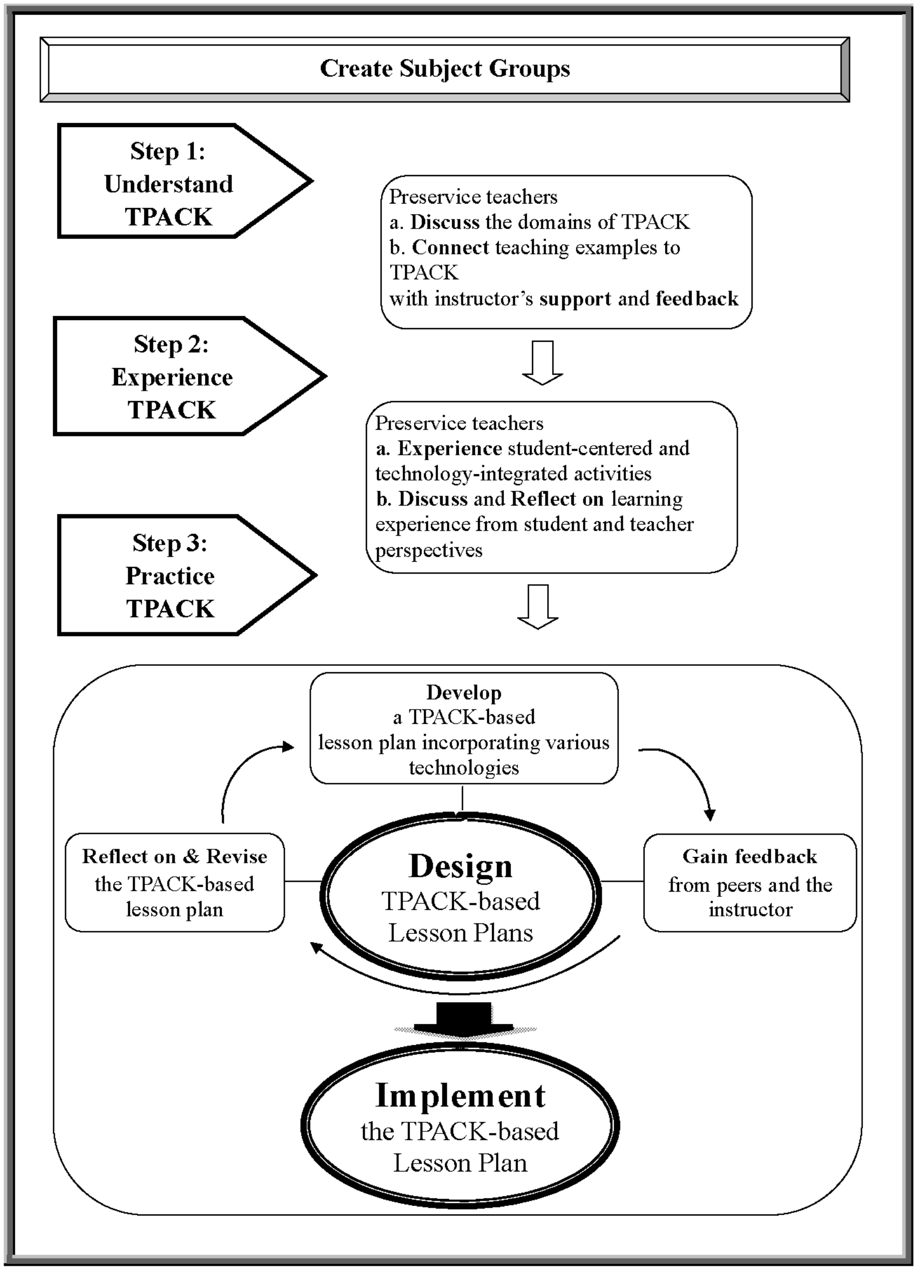

Figure 4.1. Prototype III of the TPACK-Based ID model

Step 1 is *Understand TPACK*, which was developed to build preservice teachers' knowledge base of technology integration. Two main activities comprise this step. First, the instructor does not tell preservice teachers the meaning of TPACK directly. Instead, preservice teachers *discuss* and define the domains of TPACK by researching TPACK-related materials provided by the instructor or exploring online resources by themselves. Then, in order to enhance the understanding of the integrated domains of TPACK (e.g., PCK, TCK, TPK, & TPACK), preservice teachers try to *connect* the seven domains of TPACK to technology-integrated teaching examples. The instructor's *support* and guidance to preservice teachers during their discussion process is highly important. Step 2 is *Experience TPACK*, which was developed to engage preservice teachers in a student-centered, technology-integrated learning environment so as to help them realize the associated pedagogical strategies. In this step, preservice teachers act as students and manipulate technologies to do scientific inquiry or solve higher-order thinking questions. Then, they *discuss* and *reflect on* the learning experience from teacher and student perspectives. Next, in Step 3, *Practice TPACK*, preservice teachers *develop* technology-integrated lesson plans that integrate their learning in the previous steps and also *practice* teaching the lesson plan in class.

Implementation Study

The specific objectives of this study were to develop Prototype III of the TPACK-based ID model and to examine its effects on improving preservice teachers' TPACK. The following questions guided this study:

1. What are the effects of Prototype III of the TPACK-based ID model on preservice teachers' TPACK?
2. How does the implementation study of Prototype III of the TPACK-based ID model inform the re-design of the TPACK-based ID model?

Methodology

A case study approach was adopted for this study. Based on Yin's (1994) notion, Tellis (1997) synthesized several applications for a case study: (a) to "describe the real-life context in which the intervention has occurred", (b) to "describe the intervention itself", and (c) to "explore those situations in which the intervention being evaluated has no clear set of outcomes" (the Introduction section, para. 10). Since this study attempted to understand the impact of a TPACK-based ID model (intervention) on a technology integration course in a teacher training program (real-life context) that requires contextual analysis and in-depth description (no clear set of outcomes), a case study approach was chosen.

Context and Participants

The Prototype III model was implemented in a multidisciplinary technology integration course in the Fall semester of 2012 at a university providing teacher training programs. The researcher was also the instructor of the course. Seventeen students voluntarily participated in this study (14 female, 3 male). Two participants were education majors (mathematics). The rest of the participants were from diverse majors such as advertising, business management, business and finance, communication sciences and disorders, political science, public relations, recreation and leisure studies, and sports management. The ages of the participants ranged from 19 to 26, and the average age was 20 (SD = 1.834). Excluding the two education majors, only six participants either had taken *one* education-related course before the semester or were taking one during the semester. Nine participants had never taken any education-related course until this course. The study context was consistent with the contexts of Prototypes I and II implementation studies in that the participants had diverse majors, and most of them lack teaching-related backgrounds or knowledge.

The course lasted 16 weeks and ran for three hours per week. The participants were informed that they would not only learn about technology but also learn to apply technology to support the learning of the K-12 students they would be teaching after graduation. Since the learning of TPACK requires the integration of a subject and this course was a multidisciplinary technology integration course, four subject groups were formed to facilitate the participants' TPACK acquisition according to their interests: ELA (English Language Arts), Social Studies, Mathematics, and Science groups. Technological tools taught in the course included: (1) Google Site, (2) communication and collaboration tools (e.g., Google Docs, in2Books, podcasting tools, the GLOBE Program, Blogging tools, Delicious, podcasting tools, etc.), (3) graphic software (e.g., floorplanner), (4) concept-mapping tools (e.g., Inspiration), (5) interactive animation tools (e.g., Google Earth and PhET), and (6) video creation tools (e.g., Microsoft Photo Story and iMovie),

Procedures

The course was modified according to the three steps of the Prototype III model. During the first week, every participant created a personal Google site as a digital portfolio to submit assignments over the semester, including class discussion worksheets (Google Docs), technological artifacts, lesson plans, and the group's teaching video. They were also informed of the goals and scheduled tasks of the course during the first week. Prototype III was implemented from Week 2. The participants worked with the subject group members over the semester with the aim of helping them build a solid connection between subject, pedagogy, and technology.

Step 1: Introduce TPACK. The TPACK concept was introduced in Week 2 for two class periods. In the first class period, a TPACK introductory video that explains the seven domains of TPACK was shown. Subject group members discussed the meaning of TPACK based on the video and also referred to online resources for more information to work on TPACK Worksheet-1 (in Google Docs format, see Appendix 4.A). Then, everyone recalled a past learning experience involving a teacher who taught very well and shared the example with group members. The group decided on the best example and tried to connect the example to the domains of TPACK to respond to the questions in TPACK Worksheet-1. The previous two prototypes showed that the participants had difficulties connecting the teaching example to the integrated domains of TPACK (e.g., TCK, TPK, and TPACK). Thus, the instructor supported the groups' discussion, helped them connect their examples to the TPACK domains, and provided written feedback on their answers on TPACK Worksheet-1 (Google Docs allows for multi-editors). Next, in the second class period, the instructor also provided a TPACK-integrated example (see Appendix 4.B), which attempted to help the participants review TPACK and provided them with a template to go back to correct their responses in TPACK Worksheet-1.

Step 2: Experience TPACK. In this step, seven class periods were devoted to having the participants engage in several technology-integrated, inquiry-based activities to understand student-centered strategies for technology application. The instructor had the participants act as students and demonstrated the following technological tools in different subjects: Google Earth and PhET in Science, in2Books in ELA, Photo Story in Social Studies, and concept-mapping tools in any subject area. Note that the participants knew how to use these tools (possessing TK) before they engaged in the student-centered activities.

Taking Google Earth used in Science as an example, the participants acted as students and followed the guidance "Find Glacier Change Guided Tour" (see Appendix 4.C) to learn about glacier change by using Google Earth. They searched for online resources about glacier change, found photos that illustrated glacier change, and pinned photos in the personal file created in Google Earth. They were also required to read the content on the sites where the photos were found and write a brief description for each photo pinned in Google Earth (see an example in Appendix 4.D). Thus, the personal file created in Google Earth served as a learning portfolio on glacier change. Then, the participants discussed personal findings with the subject group members and shared the group's findings with the class. After the activity, groups discussed TPACK-related questions (TPACK Worksheet-2 for Google Earth and in2books, TPACK Worksheet-3 for concept-mapping tools, and TPACK Worksheet-4 for Photo Story) that were designed to help them reflect on the learning experience from both student and teacher perspectives. An example of the question was: If you (students) found photos online and read the related content about glacier change but did not pin the photos or summarize the content in Google Earth, what would have been the difference in your learning (TPK)?

Step 3: Practice TPACK. In this step, the four subject groups learned to develop two student-centered, technology-integrated lesson plans for their subjects (11 class periods were spent) and implement a section of the lesson plan in class (1 class period for each group, 4 class periods total). They were reminded by the instructor that they should develop the lesson creatively and innovatively instead of copying the activities that they had experienced in Step 2. Each group created two lesson plans in this step. Lesson Plan 1 required each group to *develop* a teaching activity for one class period. They were encouraged to explore and apply the technologies that the class did not introduce. Then, groups reported on their lesson plans to *gain feedback* from the instructor and the classmates. Groups *reflected on* the feedback and *revised* the aspects when they developed the next lesson plan. In Lesson Plan 2, each group extended the teaching activity in Lesson Plan 1 to activities for three to four class periods that integrated various technologies learned in the class or explored by the group (*develop*). Each group also created a student Website (see an example in Appendix 4.E) in which teaching activities and associated digital artifacts were inserted for teaching purposes. Again, *feedback* was given to the groups to allow them to *reflect on* and *revise* the lesson plan before they implemented the lesson.

Finally, the four groups selected a section in Lesson Plan 2 to *implement* in the class for 30-40 minutes. All the group members were required to teach, while the rest of the classmates acted as students. Figure 4.2 presents the activities of the three steps in which the participants were engaged to learn TPACK.

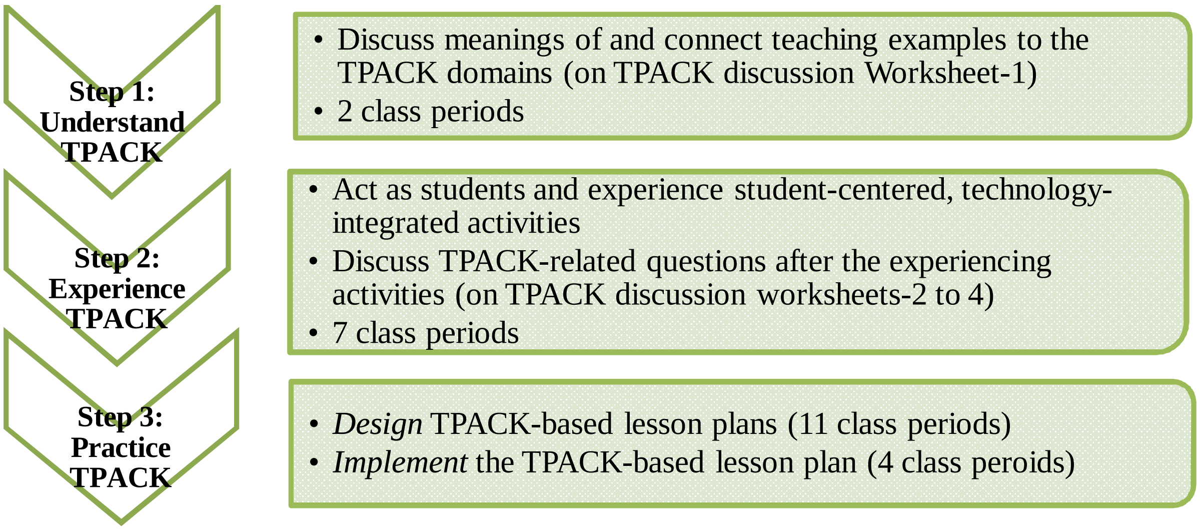

Figure 4.2. TPACK learning activities in three steps of the model

Data Collection

Data were collected from the three steps of Prototype III: (1) group discussion worksheets (TPACK Worksheet-1 to 4, Steps 1 & 2), (2) group-created lesson plans and relevant digital creations (student Websites, digital artifacts, and teaching videos taped by the instructor, Step 3), and (3) the researcher's field observation notes. Table 4.2 shows the data sources and relevant steps of the model in terms of the research questions.

Table 4.2

Data Sources and Analysis

Research Questions	Steps of the Model	Data Sources	Data Analysis
RQ1: What are the effects of Prototype III of the TPACK-based ID model on preservice teachers' TPACK?	Step 1:Understand TPACK	-TPACK discussion worksheets, -researcher's field observation notes	description and analysis
	Step 2: Experience TPACK	-TPACK discussion worksheets, -researcher's field observation notes	deductive analysis (the TPACK framework)
	Step 3: Practice TPACK	-lesson plans and corresponding digital materials -researcher's field observation notes	deductive analysis (the LoU framework)
RQ2: How does the implementation study of Prototype II of the TPACK-based ID model inform the re-design of the TPACK-based ID model?	N/A	findings of RQ1	the analysis of the findings of RQ1

Data Analysis

In Step 1, *Understand TPACK, description* and *analysis* (Wolcott, 1994) were adopted to analyze TPACK discussion Worksheet and researcher's field observation notes. According to Wolcott (1994):

> Description addresses the question, "What is going on here?" Data consist of observations made by the researcher (p. 12)...Here you become the storyteller, inviting the reader to see through your eyes what you have seen … Start by presenting a straightforward description of the setting and events. (p. 28)

> Analysis addresses the identification of essential features and the systematic description of interrelationships among them…may be employed evaluatively to address questions of why a system is not working or how it might be made to work better. (p.12)

The design principle of Step 1 emphasizes the instructor's support when the participants discuss TPACK. Thus, the instructor's observation in the setting was important because the participants' discussion process could be revealed best from the researcher's eyes. This study used *description* to present the instructor's observation in the class of the difficulties the participants confronted when they started to learn TPACK. Then, the *analysis* approach was utilized to analyze the groups' discussion worksheets that presented their understanding and improvement in TPACK. In Step 2, deductive analysis was applied (Mayring, 2000), by which data were analyzed based on precodes that were generated from the theoretical framework—TPACK. The seven domains of TPACK were utilized as the coding categories to analyze groups' discussion worksheets, in which questions were designed in terms of TPACK. In Step 3, Levels of Use (LoU, Hall, Dirksen, & George, 2006), from the Concerns-Based Adoption Model (CBAM), was employed as the coding scheme (see Table 4.3 for a detailed description). CBAM has been widely utilized in educational research in different countries to measure teachers' reactions to specific innovations (Christou, Eliophotou-Menon, & Philippou, 2004). CBAM has been also used to understand teachers' reactions to the innovation of technology integration (Ellsworth, 2000; Kim, Kim, Lee, Spector, DeMeester, 2013). In this study, the lesson plans created and implemented by the groups in Step 3 were rated based on LoU.

Table 4.3

The LOU Coding Scheme (2006)

Levels of Use (LoU) [2]	Levels of Use (LoU) in this Research Context [3]
0: Nonuse State in which the user has little or no knowledge of the innovation, no involvement with the innovation, and is doing nothing toward becoming involved.	*0: Nonuse* State in which the preservice teacher has little or no knowledge of technology integration into teaching, no involvement with the innovation, and is doing nothing toward becoming involved. For example: - A lesson is planned and/or implemented without the use of technology. - Instructional resources are limited to paper-based materials (e.g., worksheets).
1: Orientation State in which the user has recently acquired or is acquiring information about the innovation and/or has recently explored or is exploring its value orientation and its demands upon user and user system.	*1: Orientation* State in which the preservice teacher has recently acquired or is acquiring information about technology integration and/or has recently explored or is exploring its value orientation and its demands upon the educational system. For example: -The preservice teacher uses technology to *prepare* instructional materials (e.g., using a word processor to create worksheets), manage classroom tasks (e.g., sending emails, grading students' work, counting attendance, etc.), or make the instruction convenient (e.g., using a projector).
2: Preparation State in which the user is preparing for the first use of the innovation.	*2: Preparation* State in which the preservice teacher starts to use technology in teaching. For example: -The preservice teacher uses technology to support students' *understanding* or *comprehension* of the learning content using lower-level cognitive skills (e.g., memorization, organization). -Students are given opportunities to use technology to learn under preservice teachers' direction (i.e., teacher-centered strategies for technology integration).

[2] Reprinted by permission of the publisher, from *Measuring implementation in schools: Levels of Use* by G. E. Hall, D. J. Dirksen, and A. A. George, 2006, Austin: SEDL. Copyright © 2006, SEDL.

[3] The term *user* in LoU refers to *preservice teacher* in this research context; the term *innovation* refers to *the use of technology in teaching* or *technology integration*; the term *client* refers to *student*; the term *increase the impact* refers to *student learning.*

3: Mechanical use State in which the user focuses most effort on the short-term, day-to-day use of the innovation with little time for reflection. Changes in use are made more to meet user needs than client needs.	*3: Mechanical use* State in which the preservice teacher focuses most effort on the *efficient* use of technology integration with little time for reflection. Changes in use are made more to meet the preservice teacher's needs than students' needs. For example: -The preservice teacher guides students in using technology to learn the content by means of constructing concepts, building in-depth understanding, doing scientific inquiry (e.g., exploring, analyzing, and synthesizing data), and thinking critically following the preservice teacher's instruction and direction (supporting higher-level cognitive skills using teacher-centered strategies for technology integration).
4a: Routine use Use of the innovation is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving innovation use or its consequences.	*4a: Routine use* Use of technology in teaching is stabilized. Few if any changes are being made in ongoing use. Little preparation or thought is being given to improving the use of technology or students' learning results. For example: -The preservice teacher consistently and regularly guides students in using technology to learn higher-level cognitive skills while starts to give students opportunities to select or explore technologies that are suitable for their learning (the beginning of student-centered strategies for technology integration).
4b: Refinement State in which the user varies the use of the innovation to increase the impact on clients within immediate sphere of influence. Variations are based on knowledge of both short- and long-term consequences for clients.	*4b: Refinement* State in which the preservice teacher varies the use of technology to improve students' learning within immediate sphere of influence. Variations are based on knowledge of both short- and long-term learning results for students. For example: -The preservice teacher is a facilitator of students' learning and supports students in deciding what technology can best facilitate or present their learning (high level of student-centered strategies for technology integration).

5: Integration State in which the user is combining own efforts to use the innovation with related activities of colleagues to achieve a collective impact on clients within their common sphere of influence.	*5: Integration* State in which the preservice teacher use technology for teaching to make a collective impact of technology integration on student learning by allowing students to use technology collaboratively with others out of the classroom. For example: -The preservice teacher provides opportunities for or encourages students to use technology collaboratively with partnerships beyond the classroom (e.g., parents, professors, scientists, etc.) that promote their higher-level learning skills.
6: Renewal State in which the user reevaluates the quality of use of the innovation, seeks major modifications of or alternatives to present innovation to achieve increased impact on clients, examines new developments in the field, and explores new goals for self and the system.	*6: Renewal* State in which the preservice teacher reevaluates the quality of technology integration, seeks major modifications of or alternatives to achieve increased impact on students, examines new developments in the field, and explores new goals for self and the educational system. For example: -The preservice teacher makes efforts to have the learning settings seamlessly integrate with technology, in which students are engaged in student-centered, higher-order, and collaborative learning activities. Learning is impossible without the use of technology at this level.

Validity and Credibility

Triangulation is a powerful method to increase the validity and credibility of research (Merriam, 1995). Denzin (1978) discussed three types of triangulation that were mostly used by researchers—data triangulation, investigator triangulation, and methodological triangulation. Data triangulation refers to using several data sources and to understanding a social phenomenon at different times or conditions (Mathison, 1988). Data in this study included the participants' discussion worksheets, lesson plans, and digital artifacts, which were collected over a period of time (from the beginning to the end of the semester) and under different conditions (in different classes). Since the researcher was also the instructor, the field observation notes also served to triangulate the data collected from the participants.

Investigator triangulation involves more than one investigator in the research process (Mathison, 1988). The whole process of this study was reviewed by another faculty who has professed knowledge of teacher training and education. The investigator asked questions in relation to the description of research procedures and the interpretation of findings, which helped improve the rigor of this study. The investigator also casted doubt on fundamental issues such as the lack of suitable participants (preservice teachers) in this study, which aims to improve preservice teachers' TPACK. The researcher discussed with the investigator these issues thoroughly and solicited her suggestions to improve the validity of this study.

Methodological triangulation refers to the use of multiple methods to examine a social phenomenon (Mathison, 1988). Methodological triangulation in this study was established by the *case study approach* and *design-based research*. The three prototypes represented three cases in the phenomenon respectively with each *case* providing implications for the next prototype as well as for the overarching *design-based research.* Thus, the iterative enactment of the interventions (three cases of prototypes) increases the credibility and validity of the study by "increasing alignment of theory, design, practice, and measurement over time" (Design-Based Research Collective, 2003, p. 7).

Findings

In response to Research Question 1, the findings below are described in terms of the three steps of Prototype III of the TPACK-based ID model while answering the research questions

Step 1—Understand TPACK

The purpose of *Understand TPACK* was to help the participants build the knowledge base of technology integration in consideration of their lack of teaching-related backgrounds. Prototype III included the components of the instructor's immediate support and explicit explanation that attempted to facilitate the participants' TPACK acquisition. In this step, the four groups worked on TPACK Worksheet-1 in two class periods.

First class period. In this period, groups worked on (a) discussing the definitions of TPACK and (b) connecting a teaching example to the seven domains of TPACK. Using the provided online materials and personal notes taken when viewing the TPACK introductory video, groups defined the seven domains of TPACK quickly (8-10 minutes). Then, using the rest of the class time (30 minutes or so), each group discussed a good teaching example from past learning experience and connected the example to the seven domains of TPACK. The instructor walked around the class and provided support to help them connect their examples to the domains with which they had difficulties. Three out of four groups (ELA, Social Studies, and Mathematics) had difficulties connecting the group's examples to the domains of TPACK. The ELA, Social Studies, and Mathematics groups had difficulties with the domains of PK, TPK, TCK and TPK, respectively, before they discussed the core domain of TPACK. With the instructor's support, the three groups showed improvements as described below:

The ELA group. The ELA group came up with a teaching example that did not include the use of technology:

> In our AP Language classroom, our teachers taught persuasion by giving different scenarios and told us to choose if we agreed or disagreed with the example given. If we strongly agreed, we went to the very right corner of the classroom and if we strongly disagreed, we went to the far left corner. If we were somewhat undecided, we stayed in

> the middle of the room. She explained to us that it is more difficult to persuade someone in the opposite corner that your opinion was correct than it was to persuade someone who was on the fence. (Responses to TPACK Worksheet-1 from the ELA group)

The ELA group had difficulties connecting the example to PK. With the instructor's support in helping them connect their example to the TPACK domains, the group's responses demonstrated improvement in TPACK acquisition:

> We had difficulty understanding pedagogical knowledge because we didn't fully understand the meaning of pedagogical. However, after [the instructor] provided an example from our own experiences, we were able to understand that pedagogy is our understanding of different teaching methods... [The teacher in our example] used her content knowledge about persuasion and her pedagogical knowledge of interesting teaching methods (the physical movement of the students across the room versus sitting in desks and listening to a lecture) to come up with an engaging way to teach persuasion to the class. This combination of her content knowledge and pedagogical knowledge is known as PCK (Responses to TPACK Worksheet-1 from the ELA group).

The Social Studies group. The Social Studies group presented an example of a teacher using online videos to teach the Civil War. The group had difficulties connecting the example to TPK. With the instructor's support, the group demonstrated improvements in its response:

> I think this [video] was successful because teachers can reach the students on a level that they are use to. Students were more engaged in learning and tended to pay more attention…the teacher used a worksheet after the video to reflect what the student's learned and to be sure that each student understood the video. The worksheet represents

the pedagogical tool used in this lesson. (Responses to TPACK Worksheet-1 from the Social Studies group)

However, the Social Studies group also acknowledged that they did not understand TPK *thoroughly* even though they had had built a basic understanding of it: “We had problems with TPK, although we have a basic understanding, we would like to get more information on this area of TPACK” (Responses to TPACK Worksheet-1 from the Social Studies group).

The Mathematics group. The group had difficulties connecting the example to TCK and TPK. The first column of Table 4.4 shows the example presented by the group—a teacher using several different technologies (e.g., camera, Wiki, etc.) to teach the Vietnam War. The instructor helped them to connect the example to the TPACK domains. The group responded to the TCK domain, mentioning briefly the use of the webcam to talk with veterans (as shown in the second column of Table 4.4). However, the response to the TPK domain was still missing.

In sum, in the first class period, the instructor provided just-in-time support to help groups connect their examples to the domains of TPACK. The groups’ responses demonstrated improved TPACK while the understanding was not thoroughly because some responses to the TPACK domains were roughly or missing. For example, the Social Studies group acknowledged that they wanted to understand TPK more, and the Mathematics group did not respond to the TPK domain, which indicated that the groups did not understand TPACK fully.

Second class period. To advance the groups’ understanding of TPACK, the instructor provided written feedback to the groups’ responses on TPACK Worksheet-1 (in Google Docs format) before the second class period and also demonstrated an instructor-created TPACK example in the second class (see Appendix 4.B). Using the instructor-created example as a template, the groups went back to TPACK Worksheet-1 and revised their responses based on the instructor’s written feedback. Taking the Mathematics group’s responses as an example, the third column of Table 4.4 shows the instructor’s written feedback on the group’s responses generated in the first class period (as shown in the second column), and the fourth column shows the group’s revision after the written feedback and the instructor-created TPACK example were provided.

Table 4.4

Example of the Group's Responses to TPACK Worksheet-1—Mathematics

Group-Created Example	Connecting Group-Created Example to the TPACK Domains (with the Instructor's Support)	Instructor's Written Feedback	Group's Revision
My Vietnam War teacher used several different technologies to teach our subject. He visits Vietnam every 5 years and has background knowledge of the country in general. Some of these included video conferences with veterans and museums. We also used video cameras to make music videos related to the 1960s. We also created wikis and Glogsters to learn more information. We used several technological outlets to learn a lot about the Vietnam War era.	CK: He was a history teacher, grew up in that era, and has visited Vietnam several times. TK: He knew a lot about technology and used many different mediums (ex. webcams, computers, cameras, etc). TCK: ex: used the webcams to talk to veterans during class. TPACK: integrated teaching methods, previous knowledge, and his knowledge of different technologies to create an interactive classroom setting.	To CK: The teacher has strong CK. To TCK: Your group mentioned a good point about using webcams to talk to veterans. However, tell me how the method [using webcams to talk to veterans] can help students learn about the Vietnam War. Compare the following methods of using technology to think about TCK: (a) the teacher shows the video about the Vietnam War, (b) the teacher shows the video about the Vietnam War, and then the students use a webcam to talk to veterans, and (c) the teacher shows students online newspaper archives regarding the Vietnam War. Which one can help students learn better? Remember that TCK refers to the use of appropriate technology to help students best learn the content. To TPK: Include your [group's] understanding of TPK (I will show an example in the class, and your group will have time to revise responses).	TCK: Webcams help reinforce previous content that could be learned by discussion, notes, (etc). Gives students a chance to apply what they learn by communicating with real people. TPK: doing a video conference with veterans can help the teacher present material via questioning the interviewee and show students through a different perspective. It can also cover different topics that the teacher might want to explore later on.

Comparing the second and the fourth columns in Table 4.4, the responses in the second column showed that the group demonstrated a *basic* understanding of the domains of CK, TK, TCK, and TPACK. For example, the group responded to the CK domain by stating that “He [the teacher] was a history teacher, grew up in that era, and has visited Vietnam several times” and to the TCK domain by stating that “[the teacher] used the webcams to talk to veterans during class.” However, the responses to the domains of PK, PCK, and TPK were missing. The written feedback (the third column of Table 4.4) and the instructor-created example (see Appendix 4.B) were provided to improve the participants’ understanding of TPACK. For example, in the written feedback, the instructor asked the group to think about why using webcams to talk to veterans can help students learn about the Vietnam War. The instructor also asked the group to compare the use of different technologies for learning about the topic (the Vietnam War) so as to improve the group’s TCK (e.g., using webcam to talk to veterans vs. reading online newspaper archives regarding the Vietnam War).

After receiving the instructor’s feedback, the fourth column showed that the group demonstrated stronger pedagogical consideration in their revised responses to the TCK and TPK domains. For example, the revised response to the TCK domain was that “Webcams help reinforce previous content that could be learned by discussion, notes, (etc). Gives students a chance to apply what they learn by communicating with real people.” Although the group did not specifically provide responses to PK and PCK in their revised answers, the responses in TCK and TPK demonstrated improvements in their TPACK understanding.

In Step 1, gradual acquisition of TPACK was observed in the changes in all four groups’ responses to TPACK Worksheet-1. In sum, the participants’ TPACK understanding was improved by having them discuss TPACK actively, create and connect examples to TPACK with the instructor's support, and obtain explicit feedback from the instructor.

Step 2—Experience TPACK

Step 2 was designed to improve the participants' understanding of student-centered strategies for technology application by having them experience the associated activities (e.g., using Google Earth to do scientific inquiry; see the "Procedures" section for a detailed description). After the activities, the groups discussed and reflected on the learning experience by responding to TPACK-related questions (including questions concerning student-centered strategies for technology integration) on TPACK Worksheets-2 to 4. While experiencing the activities and the subsequent discussions, the participants reflected on student-centered technology integration from both student and teacher perspectives.

Table 4.5 shows examples of the groups' responses to the TPACK-related questions on TPACK Worksheets-2 to 4. Questions One (Q1) through Three (Q3) were from TPACK Worksheet-2. The four groups discussed Q1 to Q3 after they experienced student-centered activities by using Google Earth and in2Books in learning specific content. As shown in Table 4.5, in responses to Q1 (regarding TPK), the groups acknowledged the importance of student-centered strategies for technology application. They noted that offering only the teachers' demonstration of technology may result in passive learning and memorization (the Science group), while student-centered technology application facilitated students' self-directed and interactive learning (the ELA and Mathematics groups). Q2 (regarding TCK) asked groups to find different technologies to help students learn about the same topic, glacier change. In the responses, groups not only tried to explore other suitable technologies to help students learn glacier change but also had students do scientific inquiry when using the technology (e.g., the

Mathematics and Science groups had students use digital graphs to study the physical speed or time lapse of glaciers over a long period of time to understand its change). The groups' responses to Q2 demonstrated that they learned to apply technology in consideration of content as well as to promote students' higher-order thinking skills. Before working on TPACK Worksheet-2, the participants had learned how to *use* Google Earth and in2Books (possessing TK). After experiencing the student-centered activities of using Google Earth and in2Books in learning, Q3 (regarding TPK) asked the participants to describe the change in their understanding. The ELA and Social Studies groups acknowledged that they fully understood the tools after actually interacting with the tools, and the Mathematics group learned to evaluate the tools from students' learning perspectives.

Table 4.5

Examples of the Groups' Responses to TPACK Worksheet -2 to 4

TPACK-Related /Student-Centered Questions	Responses to TPACK Worksheet -2 to 4
	TPACK Worksheet-2 (experience Google Earth and in2Books)
Q1. Compared to the activity that you have experienced in the class, what difference would there be in your (students') learning if yourself did not use Google Earth but the teacher used the tool to show you numerous photos regarding glacier change? (TPK)	-Students wouldn't be able to explore it [glacier change] on their own, which helps with understanding. We prefer the activity [that we experienced in the class] because it was more self-directed. (the ELA group) -Learning by learning on your own can be beneficial because it's more interactive. Watching the teacher go through the technology can also be helpful for other students who might have difficulties with keeping up or understanding the tools. (the Mathematics group) -I think that having all the material presented to you [students] is more of a passive way to learn as opposed to using Google Earth and actively finding out the information yourself. It's more memorization when someone just shows you the material, but when you need to find it yourself it's a better way to remember and learn material. (the Science group)

Q2. What different technologies can be used to help students learn about glacier change? (TCK)	-Students could research images of glaciers on an online search engine and find information on the glaciers on National park websites, like this one. <http://www.columbiafallschamber.com>. The students are exploring on their own and can learn deeply about the information they are researching. The teacher can create a worksheet to guide the students' learning with specific questions. (the ELA group) - Using graphing technologies to show how certain glaciers have changed over time. This can work well with Google Earth because the student can see visually what this will look like, as well as study the physical speed/change over time of glaciers. (the Mathematics group) -Students could find websites that have timelapse pictures of glaciers that span many years so the effects of glacial change are visible. (the Science group)
Q3. What is the difference in *understanding* the functions of Google Earth and in2Books compared with using the tools to *experience* inquiry-based activities? (TPK)	-The experiencing activities help us learn more because we are interacting directly with the tools instead of just learning about them…[Through writing a letter in in2Books], we were able to actually go through the tool to see how it works. This helped us get a deeper understanding of the tool. (the ELA group) -The experiencing activities are vital to fully understanding a computer program. When we learned about Google Earth through [exploring educational functions of the tool], we only learned the basic ins and outs of the programs. Through experiencing activities, we pick up several skills and have a deeper understanding of how to use it to teach and learn. (the Social Studies group) -The [exploring] process gave us a better teaching perspective on using the tools because we needed to learn about how to use it and why it's helpful for a classroom tool. When we did the inquiry-based activities, we actually saw it from more of a student's perspective and how a student might work with the tool. It's important to work with the hands-on activities because you can see the viewpoint of your student's and how they would learn. Then you're able to see any difficulties or the effectiveness of the tool when learning the material. (the Science group)
	TPACK Worksheet-3 (Experience Concept-Mapping Tools)
Q4. Discuss other methods for using concept-mapping tools that you did not find in the reading materials. (TPK)	-In ELA, teachers can use concept maps to teach their students about brainstorming essay topics, or planning an essay. This helps/guides students through their writing process and can serve as a checklist for beginning writers. A non-curriculum use for concept mapping is useful, especially when planning events. The concept map can serve as a guide, plan, and checklist for planning an event. (the ELA group) -The student could use this tool for brainstorming for a paper or discussion on this subject. For students' who have trouble taking notes efficiently, this tool can help keep them on task and organize their notes. (the Mathematics group) - Instead of supplying students with key terms the teacher could allow

	the students to create a concept-map using their own terms that the students find themselves in the reading… After the students complete the work, they can compare with each other or with the teacher to make sure that the students are making the proper connection between concepts. (the Science group)
	TPACK Worksheet-4 (Experience Photo Story)
Q5. How would you design the activity to let students create digital narratives by using Photo Story on the same topic (the Civil War) by themselves or in collaboration with their parents/grandparents? (TPACK)	-By creating a family tree activity, students would develop their digital photo story on their own but use the information from their parents and grandparents that they gain through interviews. They would also research information on their own and use examples of their families that were a part of the Civil War. Hearing stories from their families would make the war more realistic and easier to comprehend. If their family had artifacts from the Civil War, they could take pictures of the objects and do research on them to find out what was culturally significant about the artifact. (the ELA group) -Depending on the age, we do think it could be an effective tool. We decided the students would need to be in high school to utilize this opportunity, yet any younger, we do not believe it would be effective. We would design the activity by assigning a very specific time period to acquire photos and information to generate a timeline photo story. (the Social Studies group) -For other historical events (within the past century), the student could interview their parents/grandparents about what their experience was like during these times. Then the student could create their own digital storytelling project based on their interview and individual research. This would give the student the freedom to explore different aspects of the historical events. (the Mathematics group) -I would design the activity specifically for the students to have to reach out to others for help because the material is simply too difficult for the young mind of the students themselves. This being the case, the students will be learning about the activity and gaining more knowledge about how to handle it than before. (the Science group)
Q6. How could we use Photo Story in subjects other than Social Studies? (TCK)	-For science, students could show clips of a particular science experiment and include a step by step explanation of what steps were taken and what the result of those steps were. For math, Photo Story could be used with in-depth word problems and use illustrations to visually show the math putting forth by the problem. For ELA, students could visually write a book report using movie clips, pictures of characters, and settings to explain the significance of each within the story they are explaining. (the ELA group) -We believe that digital storytelling would be difficult for grammar lessons, yet useful in literature for similar reasons we believe it would be useful in social studies. Although time consuming and not the easiest way to teach math, it COULD be used to show the solving of equations step-by-step. Science can also be taught this way, but it

	would be more useful in certain subjects, such as biology or astronomy, but not for chemistry and physics due to their experimental nature. (the Social Studies group) -This tool works best for subjects like history because you can create the experience of each event, and it can help the student research on their own. In the subject of math, digital storytelling can be used to add visuals to certain word problems and help the students solve them. (the Mathematics group)

Then, Q4 (regarding TPK, from TPACK Worksheet-3) asked the groups to discuss different methods of using concept-mapping tools after they read an article on educational use of concept-mapping tools, and they also created a concept map using Inspiration. The groups (ELA & Mathematics) provided creative ways to use Inspiration by allowing students to plan events (for curriculum and non-curriculum purposes) or by helping students who had trouble taking notes organize knowledge. It is worth noting that three groups (ELA, Mathematics, and Science) had students use the concept mapping tool actively during their learning processes or rather than having them passively view a concept map created by the teacher, which was observed frequently in the findings of Prototype II.

Q5 (regarding TPACK, from TPACK Worksheet-4) asked the groups to discuss student-centered strategies for using Photo Story to help students learn about the Civil War after the groups viewed a slide show created using Photo Story that told a brief story regarding the Civil War. All four groups discussed how to apply Photo Story using student-centered strategies, such as asking students to interview seniors, to look for related photos, to search for suitable materials, etc. In addition, two groups (Social Studies and Science) considered the suitability of using Photo Story in learning from student perspectives (TPK)—they mentioned that the teacher should take students' age and adults' support into consideration when young students are required to use Photo Story to create a learning product. Q6 (regarding TCK, from TPACK

Worksheet-4) asked the groups to think about other potential ways of using Photo Story in subjects other than Social Studies that they had experienced in the class (the Civil War). This question was designed to improve their TCK by considering the suitability of applying specific technology in different subjects. Groups' responses indicated that Photo Story was particularly suitable for the subjects of ELA (the ELA group), literature (the Social Studies group), history, and certain topics in Science (the Mathematics group). The Social Studies group also indicated that Photo Story would be difficult for grammar lessons. Their responses demonstrated that their evaluation of technology was based on the technology's characteristics and its relationship to different contents.

Comparing the groups' responses in Step 1 and Step 2, groups' *basic* understanding of TPACK was built in Step 1 according to their initial and improved responses on TPACK Worksheet-1 (see examples in Table 4.4). In Step 2, the groups demonstrated *advanced* understanding of TPACK according to their responses on TPACK Worksheets-2 to 4 (see examples in Table 4.5) in that the participants indicated the importance of student-centered technology application, provided constructive suggestions for the activities that they had experienced, and discussed teaching activities incorporating student-centered strategies.

Step 3—Practice TPACK

The four subject groups engaged in the *Practice TPACK* activities in Step 3 to *develop* two student-centered, technology-integrated lesson plans. The first lesson plan included teaching activities for one class period, and the second lesson plan was expanded to include teaching activities for three or four class periods (see the "Procedures" section for details). Then, the groups *implemented* a section of the second plan in the class. Since the first lesson plan served as a preliminary practice for groups to develop a lesson plan, data analysis in this step focused on the second lesson plan and its implementation. The improvement of TPACK was observed in groups' *development* and *implementation* of the lesson plans as described below.

The development of TPACK-based lesson plans. The lesson plans developed by the ELA and Social Studies groups were rated at LoU Level 4b (*Refinement*), and the Mathematics and Science groups were rated at Level 3 (*Routine use*). The plans rated at Level 3 included activities that allowed students to use technology to do inquiry and solve higher-order thinking questions. The plans rated at Level 4b additionally included activities that required students to create digital products to reflect their learning process and outcomes. Table 4.6 shows the lesson plan examples that were rated at Level 3 (the Science group) and Level 4b (the ELA group). The four groups' lesson plans are described below.

First, the four groups integrated various technologies to present the learning content (TCK). As shown in Table 4.6, for the lesson plan created by the ELA group, Google Earth, Google Lit, Inspiration, Photo Story, and Web2.0 tools were integrated to help students learn about the story "The Big Two-Hearted River" written by Ernest Hemingway. Similarly, the Science group applied interactive animation tools from PhET and Celestia, YouTube videos, digital photos, and Web2.0 tools to introduce the solar system. These tools were selected in consideration of the characteristics of the content (e.g., Google Lit for the ELA subject and PhET for the Science subject) in order to represent the content effectively (TCK was built).

Table 4.6

Examples of the Lesson Plans Developed by the Science and ELA Groups

Lesson Plan	LoU Level
Teaching group: Science **Topic and Target Age—**Middle School Students in an Astronomy course **Time needed for Assignments—**3 Days (Day 1- give information, Day 2- Celestia, Day 3- PheT/present information)	3 (Mechanical use)

Objective: Have the students learn about the Solar System and how mass and gravity affect other planets by using two hands-on tools that allow the students to explore and figure out how everything works for themselves.
Resources: Pencil/ Paper, Celestia, PhET

Day 1
Description:
-Teach the students about the solar system. They will watch a few youtube videos that shows the Solar System at a glance. The first part of this day would be consisting of a lecture where the vast majority of the textbook information is presented.
-The students will be divided into 3 groups (depending on their subject material) and then assigned a planet at random. The planet that they are assigned will be researched over the next few days and then presented to the class. (Group 1: Mars; Group 2: Saturn; Group 3: Jupiter)
Resources—videos:
1. This video provides a brief glance at the solar system and explains everything that happens in the universe to students in the classroom.
http://www.youtube.com/watch?v=fmxi3HvK2Js
2. The students will also watch this video that has been made using the Celestia program. It describes the solar system in an interesting way because it has been created using the tool that the students will use tomorrow:
http://www.youtube.com/watch?v=N7yePKJlhgw&feature=related
3. Then, the class will see a brief YouTube video that shows all of the planet's orbits around the Sun. They will be able to see that as the planets get farther away from the sun and it's gravity, they orbit at a much slower rate. This will be beneficial to understand for DAY 3 and the use of PHET.
http://www.youtube.com/watch?v=gvSUPFZp7Yo&feature=related

Day 2
Celestia Lesson Plan
Learning goal: To help middle school students learning about Astronomy with science become more familiar with the solar system by using the technological tool of Celestia.
Resources: Shatters.net/celestia
Description:
Applying this tool helps teach specific content by letting students do their own research while exploring the site. This allows them to learn more information. They do not have to have any prior knowledge on the subject matter before using Celestia. The students are able to learn all the information that they need by exploring the technological tool.
Procedure:
Answer these questions so that you can explore a little bit and familiarize yourself with the website.
1. Find your specific planet. What is the radius of this planet and all of the other

information given?
2. Click *Navigation* and then select *Star Browser*. Click on any star and give its name and luminosity.
3. Type in the constellation “Andromeda.” What information does it tell you about it?
4. Click “Navigation” and then “tour guide.” Click one of the places listed and then write down the information that is given.
5. Answer each of these questions based on the given “destinations” under the tours. Not every place will be used.
-Which is a potato shaped asteroid about 33 kilometers long?
-Which is a giant planet orbiting a red dwarf star?
-Which asteroid has a tiny satellite named Dactyl?
-What is the rate at which Pluto orbits our sun? What is the name of Pluto’s moon?
6. Press the enter button on your keyboard. This brings up the search bar. Now, type in Orion Dwarf and click “enter and the letter G.” What information is given about this?
7. Now that you have become familiar with the Celestia program, use it to answer the following question: Is the Universe Analog or Digital?

Day 3
My Solar System
Learning goal: To teach students about the effects mass and position have on gravity in solar systems.
Resources—PhET: http://phet.colorado.edu/en/simulation/my-solar-system
Procedure:
1) Select the Preset solar system "Sun and Planet". Under the initial settings you see that there are two celestial bodies. The yellow boxes correspond with the body one, and the pink boxes correspond with body two. Here you can see that the first body has 200 mass, and the second body has 10 mass. Knowing this, which body will orbit the other? Why is this? (this establishes how objects with less mass are affected by objects with more mass)
2) Now let's try changing some of the values of this model. Change the second body's X position from 150 to 75. Hit start. How has this affected second bodies orbit? (this establishes that gravity has a larger effect on an objects orbit based on how close the two objects are)
3) Now reset the model back to its default settings, and change the mass of the first body to 20. Then, change the mass of the second body to 200. Will the second body still be orbiting the first? (this establishes that planets don't necessarily orbit suns 100% of the time, its about which body has the most mass)
4) Reset the model back to its default settings again. What would happen if all objects in this model suddenly lost their velocity? (this establishes how much of an impact velocity has on orbits, without velocity planets would just crash into each other)

[p.s. More inquiry-based questions were in the student page]

Teaching group: ELA 4b
Topic: *The Big Two-Hearted River* by Ernest Hemingway (Refinement)
Subject Area: English/Language Arts
Grade Level: 9–12
Total Time: Four days

Day One and Day Two
Google Lit Trips and Google Earth
Time: The students will read *The Big Two-Hearted River* (B2HR) the weekend before the projects are assigned. The students will then be given two days to use the technology of Google Earth and Google Lit Trips and work independently on their own setting presentations.
Lesson Objective:
Students will read *The Big Two-Hearted River* by Ernest Hemingway and use Google Lit Trips and Google Earth to display their knowledge of the settings of the story to help them better understand the story's context and the importance of settings to a story.
Overview:
Make the process of learning about a story's settings easier with the integration of visual learning. This lesson uses Google Lit Trip to allow students to share with other students across the world about their understanding of the settings in *The Big Two-Hearted River*. Knowledge of the different settings can affect the interpretation of the story. In addition, visualization helps the students understand the context of the story, and it allows students to visualize places they may not have been.
Preparation:
-This lesson requires the downloading of Google Earth, which can be downloaded at www.earth.google.com.
-Access to www.googlelittrips.com for uploading final presentations.
-Access to library resources and/or the Internet would also be helpful for student research.
Process:
1. Assign *The Big Two-Hearted River* for students to read over a weekend.
2 .Explain to students that they will be using Google Earth to locate and add descriptions of 5 settings of Hemingway's short story. The descriptions would include the importance of the setting to the story and how it impacts the outcome. Pinpointing exact locations will enhance students' understanding of the cultural and geographical impact the settings have on the plot of the story.
3. Students will create a presentation to accompany their Google Earth settings and explain the importance of cultural and geographical context of the settings they chose.
4. Students will upload their presentation and a link to their Google Earth folder to the Google Lit Trips site. They will create a short introduction to their project

and post it on the site.

Day Three
Photo Story used to explain roles of main characters
Time: The third day would be devoted to the students searching the web to find appropriate pictures of how they perceived the main characters to be. Any work not finished can be completed for homework.
Lesson Objective: Students will use their knowledge of Hemingway's B2HR to illustrate the story's main characters by creating a presentation using Photo Story.
Overview: Make the process of learning about a story's main characters easier with the integration of visual learning. This lesson uses iMovie or Window's Movie Maker to allow students to create a photo story to enhance the understanding of the main characters in *The Big Two-Hearted River*. Knowledge of the main characters can help students understand the influence of people to a story. In addition, visualization of the main characters allows students to put a face to a name and create a connection between a character and readers.
Preparation:
- This lessons requires use of either iMovie or Window's Movie Maker which can be downloaded onto appropriate computers.
- Access to internet search engines is required to find images of characters
Process:
1. Students will make a list of all main characters in B2HR
2. Students will choose three of the main characters and will write a paragraph for each character explaining their influence and importance to the story.
3. Students will search images they feel accurately depict the characters they chose.
4. Students will then place images in either iMovie or Movie Maker and narrate their paragraphs with the corresponding character in their Photostory (4-integraion b).

Day Four:
Inspiration to create a concept map of the themes of B2HR
Time: One day in class to discuss the themes in B2HR. Any work not completed will be finished as homework.
Lesson Objective: Students will use their knowledge of Hemingway's B2HR to create a concept map to organize the story's themes using the online tool Inspiration.
Overview: Make the process of learning about a story's main themes more efficient by organizing them into a concept map. This lesson uses Inspiration to allow students to create a computerized concept map to organize the important themes of B2HR. Knowledge of the themes can help students understand the underlying meaning and moral lesson of the story. In addition, an organized map of the themes can help students process their thoughts in one place.
Preparation:

-Access Inspiration which was previously downloaded on the school's computers.
Process:
1. Students and teacher will discuss the important themes of B2HR and overall meaning of the story.
2. Students will draw a concept map on paper prior to transferring it to Inspiration
3. Students can add animation, pictures, colors, etc to their concept map to create relationships between the themes and overall meaning.

Second, the lesson plans developed by the four groups incorporated student-centered strategies (LoU Level 4b and above) or supported higher-order thinking skills (LoU Level 3 and above). For example, the Social Studies group (LoU Level 4b-*Refinement*) used an animation tool from Discovery.com to let students experience certain people who either survived or died in the *Titanic* disaster. The animation tool engaged students in a virtual environment as if they were passengers on board the *Titanic*. Then, students had to synthesize their learning into concept maps and create posters that included visual representations to show their learning results. Similarly, as shown in Table 4.6, the ELA group (LoU Level 4b-*Refinement*) asked students to use Google Earth to locate and add descriptions of five settings that the students thought important from the assigned reading story. Then, using the work in Google Earth, students presented the cultural and geographical impact of the settings on the plot of the story. Students were also required to upload their presentations as well as a link to their Google Earth folder to the Google Lit Trips site. Next, students had to search for images for the characters of the story and use Photo Story to introduce the characters and explain their influence and importance to the story. The lesson plans created by the Social Studies and ELA groups integrated student-centered strategies appropriately, in which students used technologies to explore real-world issues and *created* digital products to show their learning results, which required higher-level cognitive processing.

Mathematics and Science groups (LoU Level 3: *Mechanical use*) had students use animation tools to learn content related to probability and the solar system, for which higher-order learning activities were designed. Taking the lesson plan developed by the Mathematics group as an example (the lesson plan created by the Science group can be referenced in Table 4.6), the group created questions that engaged students in an inquiry-based environment to solve higher-order thinking questions of probability using physical objects (e.g., counting the percentage of colors in a pack of M&Ms and flipping coins) as well as animation tools. The students were given hands-on opportunities to use animation tools to solve higher-order thinking problems provided by the teacher. The following are some questions created by the group (Lesson Plan from the Mathematics group) to guide students in using technology *under the teacher's direction* to learn from lower- to higher-order thinking.

Q1. What do you predict the probability of flipping a coin and getting heads on the first flip? Explain.

Q2. If you were to continue flipping the coin, what percentage of the time will you end up with heads? Why?

Q3. Is this percentage still true if you flipped it 4 times? 20 times? 100 times? Explain.

Activities: Now open the "Simulation" app. [Conduct 4, 6, 20, 50, and 100 coin flips and record results].

Q4. How does this relate to your previous predictions?

In sum, the four groups' lesson plans showed that they applied their understanding of TPACK from the previous two steps (*Understand TPACK* and *Experience TPACK*) to the *development* of lesson plans (*Practice TPACK*) by integrating various technological tools to present the content (TCK) and incorporating student-centered strategies or higher-order thinking questions to help students learn the content (TPK and TPACK).

The implementation of TPACK-based lesson plans. Groups' TPACK acquisition was also observed in the *implementation* of the lesson plans. For example, the Science group (LoU Level 3: *Mechanical use*) selected *Day 3* (see Table 4.6) to teach, and on that day they let students interact with PhET (http://phet.colorado.edu/) to do scientific inquiry in the animated solar system so as to understand the relationships among the moon, sun, planets, comets, etc. Students had to manipulate the animation to respond to a series of questions that were sequenced from lower-level (e.g., levels of knowledge and comprehension) to higher-level (e.g., levels of analysis, evaluation, etc.) cognitive processing. The following were some questions that the acting students were asked when they used PhET to learn about the solar system:

[According to the animation you played in PhET, answer the following questions.]

Q1. Which planet is going the fastest? [Lower level]

Q2. About how many times does the pink planet go around while the teal planet goes around once? [Lower level]

Q3. How important do you think each planet is? [Higher level]

Q4. If one planet was missing, would the entire solar system change? [Higher level]

The ELA group (LoU Level 4b-*Refinement*) selected the last day, *Day 4,* as the section from their lesson plan to teach. They asked students to create concept maps to organize the themes and the overall meaning of "The Big Two-Hearted River", making the maps detailed enough so that a student who has not read the story would be able to understand Hemingway's themes and overall meaning. The ELA group's lesson plan was difficult to implement in the class because the teaching of the lesson plan was based on a presupposition—students had read "The Big Two-Hearted River". Thus, they provided a summary of the story for the acting students and guided them in creating concept maps. This example revealed that even though the difficult nature of implementing a student-centered, technology-integrated lesson plan, the group still took up the challenging task. In this step, the *development* and the *implementation* of the technology-integrated lesson plans revealed that the groups utilized their understanding of TPACK from Step 1 and Step 2 in the practice activities in Step 3.

Summary of Findings

In response to Research Question 1, the results of the implementation of Prototype III of the TPACK-based ID model are summarized as follows:

1. Step 1 (*Understand TPACK*): The groups' *initial* responses on TPACK Worksheet-1 indicated that the participants had a *basic* but not thorough understanding of TPACK by discussing TPACK with peers actively and connecting the TPACK domains to previously experienced teaching examples. The *revised* responses on TPACK Worksheet-1 indicated that the participants' TPACK understanding was *enhanced* after receiving just-in-time support from the instructor along with appropriate TPACK examples.
2. Step 2 (*Experience TPACK*): The groups' responses on TPACK Worksheets-2 to 4 indicated that the participants' understanding of TPACK was *advanced* in that they could evaluate student-centered, technology-integrated activities that they had experienced and provide constructive suggestions to improve the activities.
3. Step 3 *(Practice TPACK*): The groups' understanding of TPACK was applied to the development and implementation of technology-integrated lesson plans that incorporated

student-centered strategies (LoU Level 4b-*Refinement* and above) or higher-order thinking activities (Level 3: *Mechanical use* and above).

Discussion

Prototype III of the TPACK-based ID model helped preservice teachers learn TPACK in connection with their past learning experience and provided them with authentic opportunities to act as K-12 students to engage in a digital learning environment, which facilitated more understanding and implementation of student-centered technology integration than Prototype II. The design principles of Prototype III are consistent with Merrill's First Principles of Instruction (2002, 2009, 2012), integrating the five principles of *problem-centered*, *activation*, *demonstration*, *application*, and *integration* into the model, while serve as a specific framework for instructing TPACK. The findings indicated that the preservice teachers' TPACK was successfully improved by engaging in the activities in the model, and the preservice teachers applied their understanding of TPACK to the development and implementation of the lesson plans integrating student-centered strategies or higher-order thinking activities.

This study presents the third version of a TPACK-based ID model. The findings from Prototypes I and II provided critical guidelines for this study to optimize the model. In Prototype I, preservice teachers' lack of pedagogy-related knowledge was the main obstacle to their learning of TPACK. Prototype II revised the model and added components (e.g., opportunities for groups discussing TPACK actively and designing several lesson plans) to enhance preservice teachers' associated knowledge. Then, in Prototype II, preservice teachers' understanding of TPACK was improved. However, their understanding was not transferred to practice—the implementation of lesson plans was teacher-centered. Prototype III was revised to improve preservice teachers' understanding of student-centered technology application while keeping the effective components from Prototypes I and II (as described in the "Design Principles" section). There are several aspects of the three steps of Prototype III worth noting. First, in Step 1 (*Understand TPACK*), effective teaching examples could facilitate the understanding of TPACK. In the beginning of Step1, preservice teachers connected the TPACK domains to the teaching examples that were drawn from the group members' previous learning experiences. Familiar and authentic examples could serve as prior knowledge for preservice teachers to learn new materials (e.g., TPACK) efficiently and effectively (Gagné, Wager, Golas, & Keller, 2005; Hewson & Hewson, 1983), which is also consistent with First Principles of Instruction that "Learning is promoted when learners are directed to recall, relate, describe, or apply knowledge from relevant past experience that can be used as a foundation for the new knowledge" (Merrill, 2002, p. 46). Then, the instructor provided a TPACK example, which served as a template for groups to revisit their examples and correct their responses on TPACK Worksheet-1. Thus, model examples played important roles to help preservice teachers understand TPACK (Seel, 2003). Instructional designers and instructors should be aware that the selection of appropriate representations of learning materials (e.g., teaching examples) and careful arrangement of learning sequence can facilitate active learning and maximize knowledge construction (Gibbons, n.d.; Shute, Jeong, Spector, Seel, & Johnson, 2009).

Second, in Step 1, the model had preservice teachers learn isolated domains of TPACK first (e.g., TK, CK, PK, etc.) in order to facilitate their acquisition of integrated knowledge of TPACK (e.g., TPK, TCK, and TPACK). The TPACK framework emphasizes the interplay of all knowledge domains (TPACK) as opposed to considering them in isolation (Mishra & Koehler, 2006). This study found that preservice teachers need understand *each* knowledge domain before attempting to acquire integrated knowledge—TPACK. The ultimate goal of the model was to improve preservice teachers' integrated knowledge (TPACK), and the understanding of the isolated knowledge domains was the first step toward the goal.

Third, Step 2 (*Experience TPACK*) was designed to have subject groups experience student-centered, technology-integrated learning activities. This study found that subject groups could learn through observation and imitation (Bandura, 1977) when they engaged in the *Experience TPACK* activities that were designed for other subjects. For example, the instructor had all the groups use the animation tool Google Earth to learn about glacier change (the activity designed for the Science group particularly) to experience student-centered technology application. However, in Step 3 (*Practice TPACK*), all the subject groups applied animation tools to their lesson plans, which indicated that when pedagogical methods (e.g., student-centered strategies) were integrated with technology (TPK) specific to a subject area (e.g., science), different subject groups still learned that TPK through observational learning and then integrated the learning into their own subjects (TPACK). This finding is consistent with the notion that TPK transcends subject boundaries while still being critical to TPACK acquisition (Mishra & Koehler, 2006).

Fourth, in Step 3 (*Practice TPACK*), preservice teachers not only *developed* inquiry-based (Level 3) or student-centered (Level 4b) teaching activities in their lesson plans but also *implemented* them in the class. This finding was an improvement compared to the finding from the Prototype II implementation study in which 80% of the participating groups implemented lesson plans to support direct instruction or lower-level learning activities (Level 2). It should also be noted that the two components in Step 3, *gain feedback* from the instructor and *reflect on and revise* the lesson plan, were critical in helping preservice teachers actual develop and implement student-centered, technology-integrated lesson plans. For example, when groups developed Lesson Plan 1, the instructor gave *feedback* to remind the groups of the importance of including higher-order thinking questions and incorporating inquiry-based activities as they experienced in Step 2. The feedback provided groups guidance to *revise* their lesson plans to include more student-centered activities. In Lesson Plan 2 (the expanded and *revised* version of Lesson Plan 1), student-centered or inquiry-based technology application was observed in all groups. Thus, the instructor's *feedback* and the opportunities for preservice teachers to *revise* their lesson plans promoted the fulfillment of student-centered technology integration.

Re-design of the Model

In response to Research Question 2, a few aspects of the model should be modified and improved to advance preservice teachers' TPACK acquisition. First, the next prototype should evaluate which subjects and how many subject groups should be formed to amplify preservice teachers' TPACK learning. The same kind of subject groups as those in this study (ELA, Social Studies, Mathematics, and Science) or different subject groups can be formed to examine to what extent the model affects the improvement of preservice teachers' TPACK. Meanwhile, the formation of subject groups should also consider feasibility and practicality from the instructor perspective.

Second, having preservice teachers experience student-centered, technology-integrated activities (Step 2—*Experience TPACK*) needs to be processed more thoroughly. For example, this study had preservice teachers act as students to use Google Earth exploring resources and synthesizing any findings regarding glacier change in the personal folder created in Google Earth. The model should next have preservice teachers *create* a digital product for the topic, including various visual or audio materials (e.g., links, photos, videos, etc.), and present their findings in the class as if they were K-12 students to complete a challenging task. As another example, a Social Studies group can be given the task of *creating* a digital story (with grandparents/parents) to present a family's engagement in the Civil War, which can help in achieving the goal of realizing student-centered technology application deeply. The revised design includes several challenging tasks for students, in which they have to decide on a presentation topic, select technologies to afford presentation, and set a schedule or goals to accomplish.

Third, in Step 2, the discussion regarding the characteristics of student-centered strategies for technology application should be added after preservice teachers experienced the relevant activities. For example, in TPACK Worksheet-4, some groups expressed concern that young students may have difficulty with using Photo Story to create artifacts to show their learning results. If preservice teachers had understood that teachers should be facilitators when applying student-centered teaching, they might not have that concern and knew how to provide students with appropriate support. In other words, after preservice teachers experienced student-centered, technology-integrated activities, the instructor should clearly introduce student-centered strategies and its characteristics to preservice teachers, such as providing students adaptive learning experience, placing teacher as facilitators rather than directors, and having students take the responsibility of learning (Barraket, 2005; The Nellie Mae Education Foundation, 2011). If these characteristics had been explicitly explained to preservice teachers and they had been given opportunities to discuss the application of the pedagogy, preservice teachers' understanding of student-centered technology integration might have been enhanced.

Fourth, in Step 3, the development of lesson plans should collaborate with or be validated by content experts. This study acknowledged that the instructor's position in the multidisciplinary technology integration course was more a facilitator and supporter of preservice teachers' TPACK acquisition than a judge to decide the correctness of the content reflected in the lesson plans. The reality in similar settings is that an instructor of a technology integration course may not a content expert of diverse subjects, while the correctness of content in the lesson plans developed by preservice teachers should be validated. This study suggests that the next prototype can include an activity that requires preservice teachers to work with content experts to increase the quality and correctness of their lesson plans on content issues.

Limitations of the Study and Future Research Suggestions

There are several limitations of this study worth mentioning. First, four subject groups (ELA, Social Studies, Mathematics, and Science) were formed, but they represented only a partial range of subjects in schools. Future research should form subject groups in consideration of course characteristics and preservice teachers' needs to examine the effects of the model. If time permits, the instructor can have each subject group experience student-centered, technology-integrated learning activities. If time is limited, as described in the "Discussion" section, instructors can draw on the advantages of observational learning, meaning that one subject group could still learn by engaging in and observing the activities that were designed for other subject areas.

Second, a more effective evaluation framework may be needed to assess preservice teachers' actual performance of TPACK. Some surveys have been developed to evaluate preservice teachers' TPACK (Graham, Burgoyne, Cantrell, Smith, Clair, & Harris, 2009; Lux, Bangert, & Whittier, 2011; Sahin, 2011; Schmidt, Baran, Thompson, Koehler, Shin, & Mishra, 2009; Yurdakul et al., 2012). However, these surveys tend to reflect the respondents' self-perceptions of TPACK, which may be discrepant with regard to their actual performance (Lee & Kim, Under review). This study applied the LoU framework to analyze preservice teachers' actual abilities with regard to TPACK (in qualitative data such as written materials, lesson plans, etc.) since LoU is a valid and measurable scale to assess teachers' reaction to innovations. However, if a valid framework had been developed specifically for assessing actual performance with regard to TPACK, the validity of the study would have been enhanced.

Third, this study was implemented in a teacher training program. Future research should focus on retaining and transferring preservice teachers' TPACK to real classrooms. Studies point out that even though much effort has been made to improve preservice teachers' technology integration, how they transfer their learning and practice into student teaching or future teaching needs to be traced (Wilson, 2003; Wright & Wilson, 2005). Future research should trace preservice teachers' teaching when they are in schools to evaluate the effects of the ID model.

Fourth, the model was carried out by only one instructor, also the researcher. This limitation resulted in the lack of empirical data for the examination of Design Principle One—Explicit and systematic procedures. Because of the dual roles of an instructor and a researcher, the instructor familiarized herself with the purpose and procedures of the model. However, had there been other instructors, suggestions to the procedures of the model might have been provided. This study suggests that future research should examine the model involving different practitioners and including diverse settings (e.g., different subjects and methodological courses) to evaluate the model's external validity.

Conclusion

This study is the third prototype of design-based research to develop a TPACK-based ID model. By implementing and revising the prototypes continuously, the research provided empirical results showing that Prototype III effectively improved preservice teachers' TPACK in a multidisciplinary technology integration course. The model can be applied in technology integration courses in which preservice teachers have different subject majors and lack pedagogy-related background.

Using design-based research to generate an optimal solution (referring to *an effective ID model* in this study) to a complex educational problem can contribute to: (a) advancing the understanding of the fundamental theory of the research, (b) providing practical methods to the problem, and (c) reporting feasible findings in educational settings (Reeves, 2006; the design-based research collective, 2003). First, this study is a theory-driven design in that the ID model was developed based on the TPACK framework. The iterative implementation and revision of the prototypes indicated that for some domains of TPACK, the preservice teachers needed more support (e.g., PK, TCK, and TPK), and this indication led to the revision of the model. This study also pointed out the need to effectively evaluate preservice teachers' actual TPACK performance by developing an objective evaluation framework. Thus, the iterative process of development and revision in the design-based research advanced the understanding of the TPACK theory and promoted further interpretation and exploration of the theory. Second, findings of this study contributed an effective and practical model to teacher education to promote effective technology integration. The model had positive impacts on improving preservice teachers' pedagogy-related knowledge and can be applied to settings in which preservice teachers have interest in different subjects. Thus, in response to the problem that many teachers do not use technology appropriately, the model proposed in this study can be a feasible solution. Last but not least, this study applying design-based research responds to the call that educational researchers should "adopt a more socially responsible approach to inquiry" (Reeves, 2006, p. 102). van den Akker (1999) pointed out that the interrelation between theory and practice is complex and dynamic, and direct application of theory is not sufficient to solve complicated problems in educational contexts. Design-based research emphasizes heavily the need to interact with practitioners to gradually derive optimal solutions, which makes research findings accessible and feasible for educational usage. I believe this study, applying this promising research method, can facilitate teachers, administrators, instructional designers, and others in reforming educational technology.

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CHAPTER 5

CONCLUSION

The purpose of this dissertation was to provide a TPACK-based Instructional Design (ID) model for technology integration courses to improve preservice teachers' TPACK (Technological Pedagogical Content Knowledge). The design-based research approach (DBR) (DBR Collective, 2003; Reeves, 2006; Van den Akker, Gravemeijer, McKenney, Nieveen, 2006) was applied to this dissertation. Three prototypes of the TPACK-based ID model were developed, implemented, evaluated, and revised. The three prototypes were implemented in three consecutive semesters in a multidisciplinary technology-integration course with an enrollment of undergraduate students with diverse subject majors. In this dissertation, prototype implementation studies are presented in Chapter 2, Chapter 3, and Chapter 4. The progression of the three prototypes includes two aspects: (a) increasing activities to enhance preservice teachers' teaching-related knowledge from the learning of general pedagogical methods to student-centered strategies, and (b) increasing practical opportunities for preservice teachers to integrate technology in consideration of subject matter. The progression of findings from the three prototypes indicated that the preservice teachers' TPACK was improved along with the improvement of their teaching-related knowledge. Specifically, Prototype III implementation findings showed the most promise for improving preservice teachers' TPACK. In the following sections, comparisons of the three prototypes are presented, findings from each prototype implementation study are summarized, limitations of the study and future research suggestions are discussed, and implications of the study for research and practice are specified. Figure 5.1 illustrates the structure of Chapter 5.

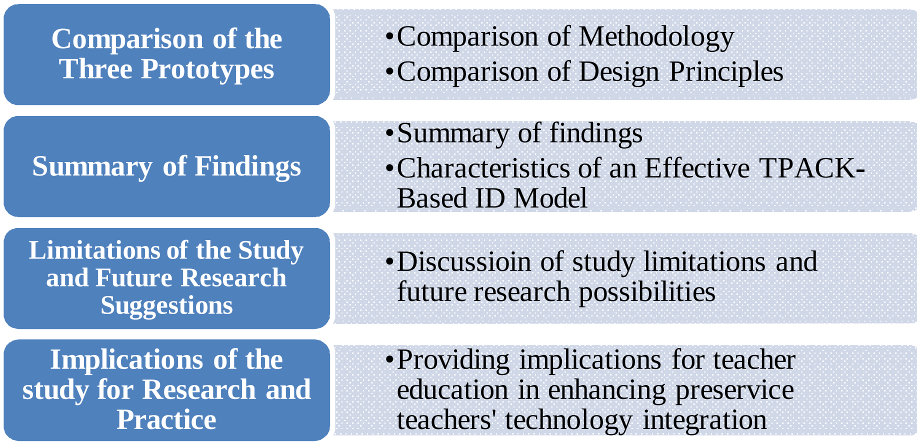

Figure 5.1. Illustrated structure of Chapter 5

Comparison of the Three Prototypes

The three prototypes of the TPACK-based ID model shared the same research goal: to develop an effective instructional design model that can be applied to teach preservice teachers with different discipline specializations. In this section, the three prototypes are compared in terms of design principles and research methodology for the implementation study.

Comparison of Research Methodology

Table 5.1 and 5.2 show the specific research questions, data collection, data analysis, and contexts and participants for each of the three implementation studies. Each implementation study was guided by two research questions: (a) to examine the effects of the model (prototype) on improving preservice teachers' TPACK (Table 5.1), and, (b) to provide suggestions for revisions and future iterations and prototypes (Table 5.2).

Table 5.1

Comparison of the Three Prototypes in Terms of Methodology (Research Question 1)

Prototype	Research Question	Model Steps	Data Collection	Data Analysis	Contexts, Participants, & Time
Prototype I (Ch2)	RQ1. What are the effects of the initial TPACK-based ID model on preservice teachers' TPACK?	1. Introduce (I) 2. Demonstrate(D)	mid-test TPACK surveys, students' written materials, instructor's field observation notes	-description (qualitative data) -descriptive statistics (survey)	A technology integration course with 20 participants in the Fall semester of 2011
		3. Develop (D) 4. Implement (I) 5. Reflect (R) 6. Revise (R)	mid- and post- TPACK surveys, groups' lesson plans and corresponding digital products, students' written materials, instructor's field observation notes	-paired t-test, -deductive analysis (the TPACK framework)	
Prototype II (Ch3)	RQ1: What are the effects of Prototype II of the TPACK-based ID model on preservice teachers' TPACK?	1. Understand TPACK	TPACK discussion worksheets, instructor's field observation notes	description and analysis	A technology integration courses with two class sections with 38 participants in the Spring semester of 2012
		2. Engage in TPACK	individuals' and groups' lesson plans and corresponding digital artifacts, instructor's field observation notes	deductive data analysis (the LoU framework)	
		3. Practice TPACK	groups' lesson plans and corresponding digital artifacts, teaching videos, instructor's field observation notes		

Prototype III (Ch4)	RQ1: What are the effects of Prototype III of the TPACK-based ID model on preservice teachers' TPACK?	1. Understand TPACK	TPACK discussion worksheets, instructor's field observation notes	description and analysis	A technology integration course with 17 participants in the Fall semester of 2012
		2. Experience TPACK	TPACK discussion worksheets, instructor's field observation notes	deductive analysis (the TPACK framework)	
		3.Practice TPACK	lesson plans and corresponding digital materials, instructor's field observation notes	deductive analysis (the LoU framework)	

Table 5.2

Comparison of the Three Prototypes in Terms of Methodology (Research Question 2)

Prototype	Research Question	Model Steps	Data Collection	Data Analysis
Prototype I (Ch2)	RQ2. How do the results of the initial TPACK-based ID model inform future designers or researchers of design principles for the revision of the model?	N/A	findings of RQ1	analysis of the findings of RQ1
Prototype II (Ch3) & Prototype III (Ch4)	RQ2: How does the implementation study of Prototype II of the TPACK-based ID model inform the re-design of the TPACK-based ID model?			

The third column of Table 5.1 shows the steps in applying the model for each prototype, and the columns "Data Collection" and "Data Analysis" were based on these model application steps. The TPACK survey was conducted in Prototype I but not in Prototype II and III implementation studies because the findings from the Prototype I implementation study indicated that there was a discrepancy between preservice teachers' self perceptions about their TPACK and their actual performance using TPACK. The quantitative data might be collected in all the three studies for other purposes. However, since the major purpose of this DBR research was to improve the model to effectively support learners' development of TPACK, the information from the survey was deemed uninformative for this research. In other words, data collected from the progressive development of teachers' TPACK would be much more informative with regard to improving the design and development of the model.

Comparison of Design Principles

Design principles guided the revision and development of the three prototypes of the TPACK-based ID model. Figure 5.2 shows the design focus of each prototype, and Table 5.3 presents the design principles of the three prototypes as well as the process of prototype modifications.

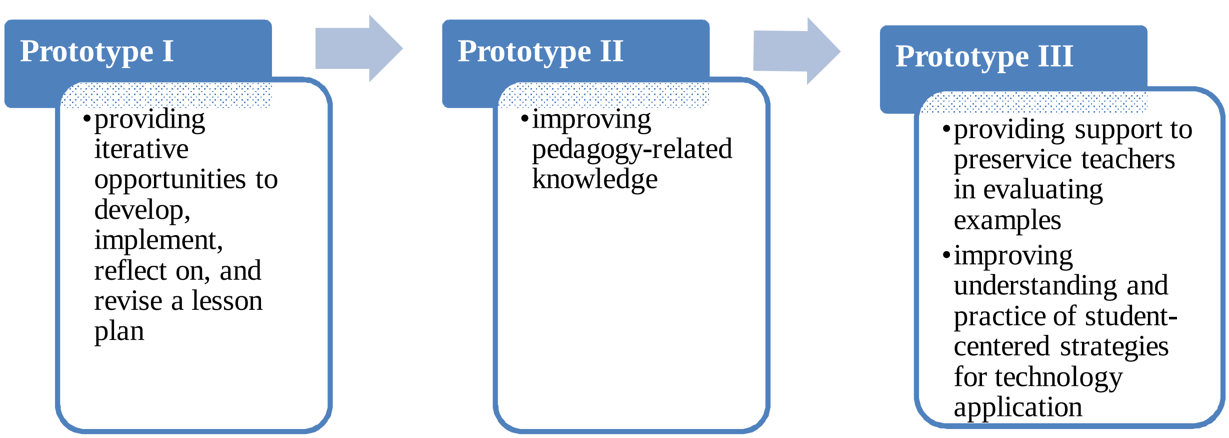

Figure 5.2. Design focus of each prototype

Table 5.3

Comparison of the Three Prototypes in Terms of Design Principles

Design Principles in Prototype I	Change	Design Principles in Prototype II	Change	Design Principles in Prototype III
Principle 1. Explicit and systematic procedures: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.	No change	**Principle1. Explicit and systematic procedures**: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.	No change	**Principle 1. Explicit and systematic procedures**: Clear stages can provide practical solutions for teacher training programs to enhance preservice teachers' TPACK.
Principle2. TPACK introduction and demonstration stages: Introducing the TPACK theory can build preservice teachers' knowledge base of technology integration, and demonstrating technology-integrated examples can prepare them for designing technological teaching artifacts.	Includes the changes to improve pedagogy-related knowledge	**Principle 2.Understand TPACK:** Preservice teachers' discussion of definitions, creation of examples, and comparison of teaching examples regarding TPACK can enhance understanding of the domains of TPACK.	Include instructor's active support during students' evaluation of technology-integrated teaching examples	**Principle 2. Understand TPACK:** Preservice teachers' discussion of TPACK and evaluation of technology-integrated teaching examples relevant to previous learning experience with the instructor's active support can enhance understanding of TPACK.
			Include the changes to (a) support understanding of student-centered technology application, and (b) transfer the understanding to teaching practice (a)	**Principle 3. Experience TPACK:** Opportunities for preservice teachers to experience student-centered, technology-integrated activities can facilitate the understanding of student-centered technology application.
Principle3. Design-based learning activities: Creating a lesson plan and a corresponding digital artifact can prompt preservice teachers to analyze the subject content and learning needs of students.		**Principle 3. Engage in TPACK:** Opportunities for preservice teachers to develop, discuss, and revise a lesson plan for each of the technological tools can enhance the connection of technology to a specific subject and pedagogy.	(b)	**Principle 4. Practice TPACK:** Opportunities for preservice teachers to design, gain feedback on, reflect on, revise, and implement student-centered, technology-integrated lesson plans can enhance the understanding as well as the practice of student-centered technology application.
Principle4. A cyclic design-based learning process: Opportunities for preservice teachers to go through the design process—implementation, reflection, and revision of a lesson plan and a corresponding digital artifact—can enhance the learning of TPACK.		**Principle 4.Practice TPACK: Integrating technological tools to design a learning activity:** Opportunities to integrate several technologies to develop a lesson plan and opportunities to implement, reflect, and revise the lesson plan help transfer knowledge to practice.		

The initial design principles were derived from the theoretical frameworks of TPACK (Mishra & Koehler, 2006; Koehler & Mishra, 2009), the *Learning by Design* approach (Kalantzis & Cope, 2005; Kali, Levin-Peled, & Dori, 2009), and three existing ID models proposed to improve preservice teachers' technology application (Angeli, 2005; Angeli & Valanides, 2005; Jang & Chen, 2010). The four design principles of Prototype I (see Table 5.3) focused on providing preservice teachers with *iterative opportunities* (see Figure 5.2) to go through the process of development, implementation, reflection, and revision for a lesson plan. Findings and suggestions from the Prototype I implementation study indicated that the lack of teaching-related background or pedagogy-related knowledge hindered preservice teachers' learning of TPACK. This indication led to the revision of Prototype I design principles and the development of Prototype II. Four design principles were proposed in Prototype II, of which Principle 1 was from Prototype I and Principles 2, 3 and 4 were revised to enhance preservice teachers' *pedagogy-related knowledge* (the design focus of Prototype II). Based on the Prototype II implementation study findings, Prototype III focused on providing *support* to preservice teachers' evaluation of technology integration examples and improving *student-centered strategies* in technology integration. According to the design principles, three prototypes of the TPACK-based ID model were developed (Appendices 5.A, 5.B, and 5.C).

The progressive improvements of the design principles of the three prototypes are further analyzed retrospectively. The initial design principles are generally compatible with First Principles of Instruction (Merrill, 2002, 2009, 2012), as shown in Table 5.4, but served as a more specific elaboration for the teaching of TPACK. The design principles were continuously revised based on findings and suggestions from each prototype implementation study. The subsequent refinements of the design principles are toward more alignment with Merrill's principles, particularly in Prototype III involved ensuring that preservice teachers were: (a) engaging in a *problem-centered* environment to work on teaching tasks, (b) learning TPACK in connection with past experience (*activation*), (c) observing the instructor's teaching *demonstration* of technology-integrated, student-centered activities, (d) applying TPACK understanding to develop lesson plans (*application*), and (e) implementing lesson plans as if they were real teachers (*integration*).

Table 5.4

A Progression of Increasing Compliance With Merrill's Fist Principles of Instruction

First Principles of Instruction	Prototype I	Prototype II	Prototype III
Problem/task-centered	✓	✓	✓
Activation (helping learners connect prior knowledge to new knowledge)	X	X	✓ P2 (Understand TPACK—Preservice teachers' connected TPACK to their previous learning experience)
Demonstration (showing the learning content)	Δ P2 (TPACK Introduction and Demonstration—a teaching example relevant to history subject was demonstrated)	Δ P2 (Understand TPACK—two teaching examples (good example and non example) were demonstrated for discussion and evaluation)	✓ P3 (Experience TPACK—student-centered strategies for technology integration in different subject areas were demonstrated)
Application (allowing learners to apply new knowledge on tasks)	✓ P4 (Design-Based Learning Activities—preservice teachers developed a technology-integrated lesson plan)	✓ P3 (Engage in TPACK—preservice teachers developed several technology-integrated lesson plans)	✓ P4 (Practice TPACK—preservice teachers developed student-centered, technology-integrated lesson plans)

Integration (allowing learners to apply new knowledge to real life settings)	✓ P4 (Design-Based Learning Activities—preservice teachers taught the lesson plan)	✓ P4 (Practice TPACK— preservice teachers taught the lesson plan)	✓ P4 (Practice TPACK—preservice teachers taught the lesson plan)

* Symbol ✓means that the principle of the associated prototype meets the principle of First Principles of Instruction; ∆ means that the principle of the associated prototype *partially* meets the principle of First Principles of Instruction; X means that the principle of the associated prototype does *not* meet the principle of First Principles of Instruction.
* P2 refers to Principle 2 of the associated prototype, and so forth.

Summary of Findings

Table 5.5 presents the summary of findings from each implementation study. The Prototype I implementation study did not indicate desired outcomes. Preservice teachers' integrated knowledge of TPACK (TPK, TCK, and TPACK) was not improved in that their understanding of integrated knowledge was still the *combination* of content, pedagogy, and technology knowledge without the consideration of the interrelationships among them. The Prototype I implementation study suggested that the model should improve the preservice teachers' pedagogy-related knowledge so as to facilitate their learning of TPACK. Another critical finding was that the preservice teachers rated their TPACK higher than their actual knowledge (scores of either 4 or 5 out of 5) observed in their lesson plan and implementation.

In Prototype II, components to improve *pedagogy-related knowledge* were added to the design principles and the Prototype II model. The *LoU* framework (Hall, Dirksen, & George, 2006) was used to analyze qualitative data (e.g., TPACK discussion worksheet, lesson plans, teaching videos, etc.). Findings from the Prototype II implementation study indicated that the preservice teachers' *understanding* of TPACK was improved after engaging in Step 1 (*Understand TPACK*) and Step 2 (*Engage in TPACK*), which was observed in the improvement of the level of technology integration in preservice teachers' initial- and final- created lesson plans. However, their understanding was not fully utilized in their teaching practice when they implemented their lesson plans in the class. All 10 participating groups applied teacher-centered strategies in their lessons—using technology to support direct instruction and/or to only allow students to use technology to carry out teacher-directed tasks. The findings led to the revision and development of Prototype III model.

To enhance not only preservice teachers' understanding of TPACK but also their practice of TPACK, in Prototype III, two components were emphasized: (a) providing *support* (e.g., explicit explanations and written feedback on preservice teachers' discussion) to help them apply TPACK to evaluate technology-integrated teaching examples and (b) improving their *student-centered strategies* for technology application. Findings from Prototype III showed that preservice teachers' TPACK was promoted in both knowledge and teaching practice by developing and implementing student-centered lesson plans.

Table 5.5

Summary of Findings From the Three Prototypes' Implementation Studies

Prototype I	Preservice teachers showed basic understanding in the domains of TK, PK and CK, while no evidence was found in the integrated domains of TPK, TCK, and TPACK. Their understanding of TPACK was limited to the combination rather than integration of technology, pedagogy, and content. However, preservice teachers' self-assessed TPACK was not aligned with their actual performance of applying the knowledge to develop and implement technology-integrated lesson plans.
Prototype II	Preservice teachers' TPACK understanding was improved by engaging in the activities of discussing TPACK actively (Step 1—*Understand TPACK*) and developing several technology-integrated lesson plans (Step 2—*Engage in TPACK*). However, their TPACK understanding was not fully utilized in teaching practice (Step 3—*Practice TPACK*) because the implementation of technology-integrated lesson plans were mainly teacher-centered.
Prototype III	Preservice teachers' *basic* understanding of TPACK was built in Step 1 by discussing TPACK actively (*Understand TPACK*) and the understanding was *advanced* in Step 2 (*Experience TPACK*) by engaging in student-centered, technology-integrated activities. Their understanding of TPACK was successfully transferred to Step 3 (*Practice TPACK*), in which they developed and

	implemented technology-integrated lesson plans that incorporated student-centered strategies or higher-order thinking skills.

Characteristics of an Effective TPACK-Based ID Model

The characteristics of an effective TPACK-based ID model are reflected in the following design principles derived from the implementation of the three prototypes:

1. **Explicit and systematic procedures:**

The practical steps that comprise the TPACK-based ID model were developed based on instructional design. According to Gustafson and Branch (2002):

> Instructional design is a systematic process that is employed to develop education and training programs in a consistent and reliable fashion…The system approach implies an analysis of how its components interact with each other and requires coordination of all design, development, implementation, and evaluation activities. (p. 11)

The components (procedures) of the TPACK-based ID model had been developed rigorously by analyzing related theories and integrating the activities of design, development, implementation, and evaluation. Then, the model was examined empirically and iteratively, which provided suggestions for the revision of the interaction among the components (procedures) so as to amplify the model's effects. The following are the four effective components (procedures) to promote preservice teachers' TPACK in a multidisciplinary technology integration course that derived from implementation findings of the three prototypes of a TPACK-based ID model.

2. **Creating subject matter groups:**

Findings showed that preservice teachers' TPACK learning in subject matter groups had two advantages. First, learning with peers allowed preservice teachers to discuss the meaning of TPACK collaboratively, share TPACK-related learning thoughts and experience, and clarify their understanding of TPACK, which was helpful for the preservice teachers' grasp of the concept of TPACK. Second, engaging in the subject group placed preservice teachers in an environment that prompted them to consider subject matter regularly and automatically when they designed any technology-integrated activity, which strengthened their TPACK acquisition.

3. **Building knowledge based of TPACK (Understand TPACK):**

Preservice teachers who had a basic understanding of the definitions and meanings of the domains of TPACK facilitated their learning of technology integration. The understanding of TPACK requires teaching-related backgrounds or associated supporting knowledge; however, preservice teachers in this study lacked the knowledge. This study used the following strategies to improve preservice teachers' teaching-related knowledge so as to facilitate their TPACK acquisition: discussing TPACK actively, connecting TPACK domains to familiar teaching examples with the instructor's support and feedback, and reviewing good TPACK teaching examples provided by the instructor.

4. Engaging in a student-centered, technology-integrated learning environment (Experience TPACK):

Findings showed that the preservice teachers' understanding of TPACK was advanced by engaging them in several student-centered, technology-integrated learning activities as if they were K-12 students. After experiencing the activities, preservice teachers understood the difference between a teacher's use of technology to demonstrate materials and students' use of technology to learn. Findings also indicated that different subject groups could learn student-centered, technology-integrated strategies for technology integration when they engaged in the associated activities that were designed for other subject groups.

5. **Transferring knowledge to practice (Practice TPACK):**

After preservice teachers had a basic understanding of TPACK, asking them to develop and implement technology-integrated lesson plans could strengthen their understanding of TPACK as well as promote the application of their TPACK understanding to teaching practice. It is critical that the instructor should remind preservice teachers of the student-centered activities that they had experienced previously and give feedback to support them in developing student-centered lesson plans.

Limitations of the Study and Future Research Suggestions

This research has the following limitations. First, the interpretation of the data was likely influenced by the researcher's personal beliefs because the researcher was also the instructor in the research context. Based on Schwartz and Schwartz (1955), the researcher's role in this study could be classified as that of an active participant observer, in which the observer "maximizes his [her] participation with the observed in order to gather data and attempts to integrate his role with other roles [participants] in the social situation. His [Her] activity is accepted, both by himself and by the observed" (p. 349). Schwartz and Schwartz (1955) also discussed the limitations of the role by indicating that "there is increased possibility of affective involvement with the observed so that the observer loses his [her] perspective—especially the perspective of the outsider" (p. 349). It is possible that the interpretation and the evaluation of the three prototypes of the implementation studies interweaved the views of an instructor and a researcher, although several triangulation strategies such as data triangulation, peer review, methodological triangulation had been adopted. Findings might have been greatly different if the researcher had not been the instructor but a complete observer or if the model had been implemented by several other instructors. This limitation also led to the lack of empirical data to examine Design Principle One—Explicit and systematic procedures. Since no other instructors had been participated, feedback from other instructors to revise the procedures was inaccessible. Future research should have different practitioners implement the model.

Second, in Prototype III, the study only formed four subject groups (ELA, Social Studies, Mathematics, and Science) to help preservice teachers learn TPACK. It was possible that some preservice teachers in this study wanted to learn technology integration specifically designed for their subjects of interest. It is also possible that different design of groupings may affect the results (e.g., grade-level groupings, grade-level within subject matter discipline groupings, etc.). Future research should examine carefully what and how many subject groups should be formed in consideration of time, teaching materials, and preservice teachers' needs as well as other objective (e.g., state requirements) and subjective (e.g., subject preference) factors so as to provide preservice teachers the optimal learning choice.

Third, the internal validity of the study should be improved by involving more practitioners and peer reviewers. If more practitioners had been participated, the study's validity could have been improved by the member checks strategy (Merriam, 1995). In addition, more peer reviewers or investigators (Mathison, 1988; Merriam, 1995) should also be included so as to examine the plausibility of the emerging findings.

Finally, external validity of this research should be improved. Preservice teachers' actual performance of TPACK should be traced in their first two or three years in the classroom as compared to their performance in teacher training programs. A control group with no TPACK preparation may also provide comparable data to examine the model. To develop the local effects into generalizable effects, more evaluations should be conducted in diverse settings such as different teacher training programs and subject-specific or methodology courses.

Implications of the Study for Research and Practice

This implementation study provided supportive evidence for the TPACK framework by indicating that the development of and teaching practice for student-centered, technology-integrated lesson plans required an integrated understanding of content, pedagogy, and technology (Mishra & Koehler, 2006). Researchers have argued that different pedagogical ways to represent the subject affect students' learning (Shluman, 1986) and preservice teachers should "develop a clear and appropriate pedagogical rationale for incorporating computer technologies in their classrooms" (Angeli, 2005; p. 394). Consistent with these arguments, this study found that preservice teachers' pedagogy-related knowledge served as a critical basis to understand integrated relationships among content, pedagogy, and technology. Preservice teachers' insufficient teaching experience could lead to the lack of pedagogy-related knowledge and affect their understanding of TPACK. Thus, teacher training programs should enhance preservice teachers' pedagogy-related knowledge when teaching technology integration.

Angeli (2005) suggests that the instructor explicitly teach the unique features of specific technology with regard to how it supports the representation of learning content. In this study, the TPACK-based ID model responded to the call by providing activities that had preservice teachers discuss and evaluate technology-integrated teaching examples actively (i.e., *Understand TPACK*), engage in technology-integrated environment and learn student-centered activities authentically (i.e., *Experience TPACK*), and design and implement technology-integrated lesson plans (i.e., *Practice TPACK*). It should be noting that the TPACK building process requires various and systematic supportive activities and the learners should engage in these activities over a period of time. In other words, the real understanding of TPACK does not merely refer to *knowing* the meaning of TPACK but also to possessing abilities to *apply* the knowledge in teaching practice (developing and implementing TPACK-based lesson plans).

Conclusion

This DBR study resulted in a reasonably refined ID model for TPACK training in a preservice curriculum that is appropriate for a multidisciplinary technology integration courses. Use of the refined model is likely to improve preservice teachers' TPACK. Moreover, the refined model can be used as a point of departure for further development and deployment in future studies and preservice teacher preparation courses.

The practical and systematic strategies in the model were designed in consideration of preservice teachers' different subject interests and their lack of teaching-related knowledge, which can provide guidelines for future research to promote technology integration in multidisciplinary technology integration courses. The ultimate goal of this study is to prepare preservice teachers to become better able to apply technology to teaching in the classroom that can effectively engage students in a learning environment and improve their learning results.

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APPENDIX 3.A

TPACK WORKSHEET-1

Class Section:

Group members: Date:

Discuss the following questions and return the paper to the instructor.

1. Draw the figure of TPACK.
2. Use your words to give a definition of CK.

    2.1 Give 5 words, phrases, or examples that belong to CK.

3. Use your words to give a definition of TK.

    3.1 Give 5 words, phrases, or examples that belong to TK.

--------------------------------Class discussion before the last question---------------------------

4. Use your words to give a definition of PK.

    4.1 Give 5 words, phrases, or examples that belong to PK.

APPENDIX 3.B

TPACK WORKSHEET-2

Class Section:

Group members: Date:

Discuss the following questions and return the paper to the instructor.

Part I

1. TPACK review
   1) Based on your learning in TPACK Worksheet-1, draw the TPACK picture and give some examples to CK, PK, and TK.
   2) Being teachers to teach your group member(s) who was/were not here on Friday about TPACK. Write here the learner(s)' name:________________________

2. We will view two videos to learn integrated knowledge— TPK, TCK, PCK, and TPACK. Let's watch Video1 first.

   1) According to the video, what topic/subject was taught (CK)?

   2) Why is the topic difficult to teach using traditional methods, such as lectures (PCK)?

   3) What technological tool(s) were used by the teacher in the video (TK)?

   4) Why is the technological tool used by the teacher in the video helpful for that topic (TCK)?

   5) Circle the importance of the technological tool(s) for the content
      Not important 1 2 3 4 5 6 7 8 9 very important

   6) Compared to traditional methods, how did the tool(s) represent/transform the content into forms that are comprehensible or that made it easier for learners to realize the content (TCK)?

   7) In what activities were the students engaged when using technological tools according to Video 1(TPK)? (p.s. They should use the tool(s) not only for fun but also for constructing their knowledge, such as solve problems and think critically)

Part II

3. Now, you will view video 2 and answer the following questions
   1) According to the video, what topic/subject was taught (CK)?
   2) Was the topic difficult to teach using traditional methods (PCK)? Why? If no, tell me some methods that are suitable for this topic.

3) What technological tool(s) were used by the teacher in Video 2 (TK)?

4) Are the technological tool(s) unique, necessary, and helpful for that topic (TCK)?

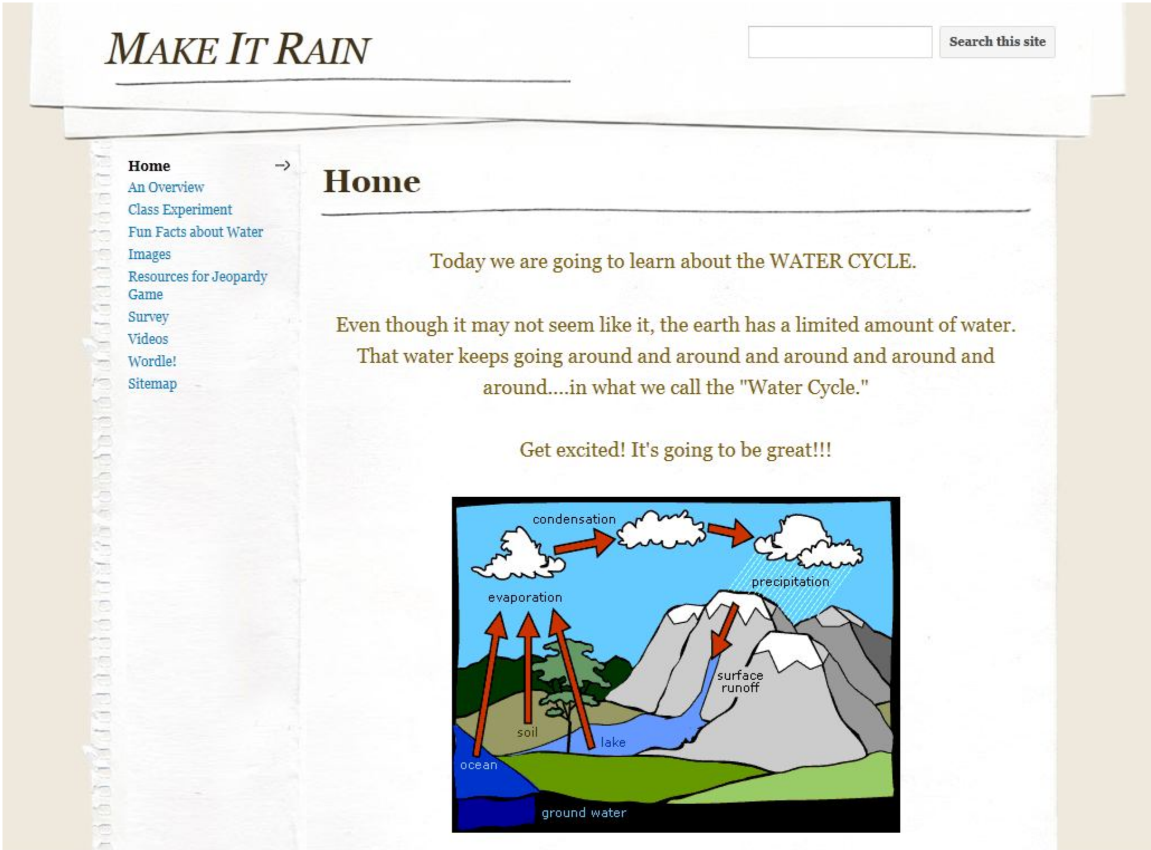
   Circle the importance of the technological tool(s) for the content
   Not important 1 2 3 4 5 6 7 8 9 very important

5) In what activities were the students engaged when using technological tools according to Video 2 (TPK)?

4. Comparing the two teaching videos, in which one do you think that the technology better represented/transformed the content into forms that are comprehensible and that made it easier for learners to realize the content? Why? (TPACK)

APPENDIX 3.C

AN EXAMPLE OF STUDENT WEBSITE


MAKE IT RAIN
Search this site
Home
An Overview
Class Experiment
Fun Facts about Water
Images
Resources for Jeopardy Game
Survey
Videos
Wordle!
Sitemap
Home
Today we are going to learn about the WATER CYCLE.
Even though it may not seem like it, the earth has a limited amount of water. That water keeps going around and around and around and around and around....in what we call the "Water Cycle."
Get excited! It's going to be great!!!
condensation
precipitation
evaporation
surface runoff
soil
lake
ocean
ground water

APPENDIX 4.A

TPACK WORKSHEET-1

Based on your group's research on TPACK, write your group's discussion.

1. What is your group's understanding of the seven domains of TPACK?

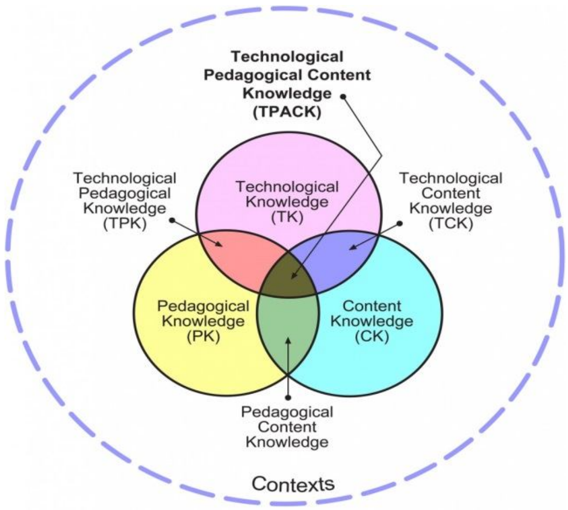
2. Think about a teacher that he/she taught very well. Tell your group members why the teacher taught well. Then, select an example (no limit of the subject, but will be best if in your subject area). Write the story/example of the teachers' teaching here.

3. Try to connect the example to the 7 domains of TPACK? Write your groups' discussions here or/and draw on the TPACK paper passed out to you if you need.

4. What domains of TPACK your group has difficulties understanding? What the difficulties are they?

APPENDIX 4.B

INSTRUCTOR-CREATED TPACK EXAMPLE



1. CK: track & field (e.g., start to run), baseball (pitch a ball)
2. PK: a coach's demonstration, see other teams or other athletes' performances (traditionally).
3. PCK: a coach's demonstration can show you correct poses when starting to run or improving your pitching velocity, and
your coach guides you to see other athletes' performances can help you learn different skills.
4. TK: a video(videotape your poses when you start to run or gestures when you pitch a ball).
5. TCK: a video shooting your performances help you horn skills in running or pitching easily because you can find what aspects you need to correct or learn more. (They are difficult to find without technology)
6. TPK: video can show you a whole process of your performances (visualization), give visual feedback, catch a specific moment, give unlimited chances for review (easy to fast-forward and back forward), slow down a series of motions, etc.

APPENDIX 4.C

FIND GLACIER CHANGE GUIDED TOUR

Open Google Earth.
From the PLACES menu on the left of the screen, select "My Places".
In the top toolbar, select ADD, then FOLDER.
Name the folder (ex. Glacier Change Lily).
Click OK, you will see the folder appear in the My Places list on the left.

Warm Up
In the SEARCH menu on the left of the screen, choose the "Fly To" tab and type in the name of a location that you would like to start from (ex. Juneau, AK).
Click on the magnifying glass to begin your search.

Zoom in or out using the vertical + ... – scale on the right of your screen.
Move in different directions with the arrows inside the compass.
Rotate your view using the compass circle.
Change your tilt viewpoint by using the horizontal x . . . . – scale on the right of your screen. It is important to use these features in examining your glacier to provide the best angle to both identify and illustrate key characteristics of a glacier.

Start the Tour
You will find 6 images that show the changes of glacier in different locations. You will also read the webpage that the image located to summarize important facts about glacier change, such as causes, potential impact to the environment and human life, or feasible solutions.

1. Go to the example image, which shows the change of McCarty Glacier:
http://www.wrd.org/engineering/central-west-coast-basin-climate-change.php

2. Right click on the first image, and choose PROPERTIES from the menu. Copy the URL Address of the image.

3. Go back to Google Earth, fly to "McCarty Glacier" → Find the pushpin button at the top tool bar→ ADD PLACEMARK"→ Give a name to this location →ADD Image→past URL of the example image→hit OK.

4. You can find that the location has been saved under "My Places". Read the story about McCarty Glacier and add 2 paragraphs to summarize your understanding about McCarty glacier change in the description box.
My Places→ right click on the example location→properties→add the description about this glacier

5. You have to explore at least 6 images online along with insightful description about glacier change. Focus on key features of the glacier, such as the snowline, lakes on or at the terminus of the glacier, streams on the glacier surface, trimlines, freshly deglaciated areas, icefalls, causes, potential impact to the environment and human life, or feasible solutions, etc.

Some resources:
Juneau Ice field material description:
http://www.nichols.edu/departments/Glacier/juneau%20icefield.htm
North Cascade Glacier Background data http://www.nichols.edu/departments/Glacier/

6. When you are ready to save, right click on your folder, choose SAVE AS and save it to your computer.

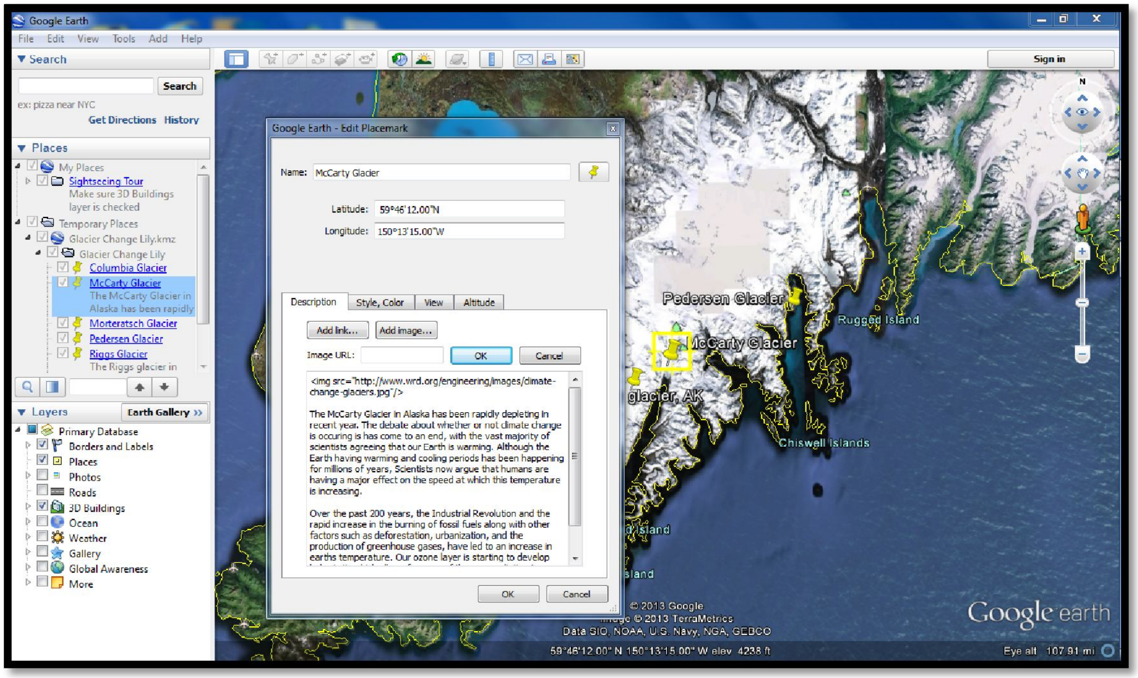
Analyze Findings

Based on the pictures you have pinned and your exploration of glacier change, what important issues emerge? Discuss and share your findings, reflections, and thinking with your subject group members. Then, summarize a few features from your group.

Sources: Using Google Earth to study Glaciers
http://www.curriki.org/xwiki/bin/view/Coll_mrsamatulli/UsingGoogleEarthtoStudyGlaciers?bc=

APPENDIX 4.D

EXAMPLE OF A PRESERVICE TEACHER'S WORK OF USING GOOGLE EARTH TO LEARN GLACIER CHANGE



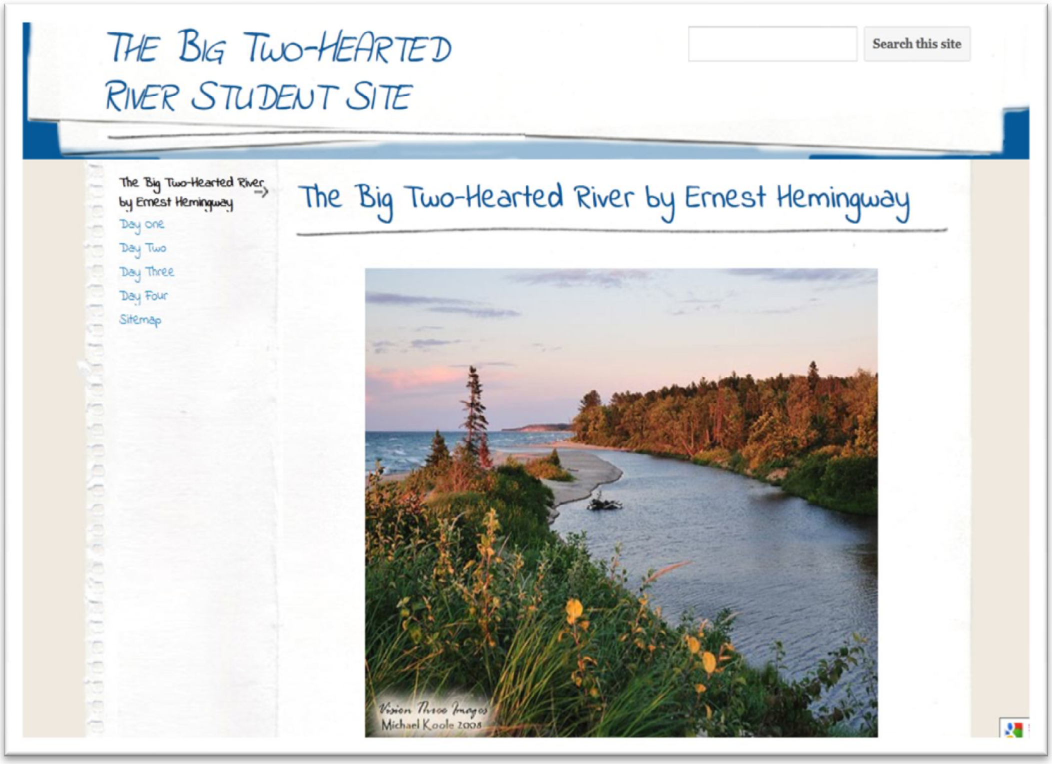
Google Earth - Edit Placemark
Name: McCarty Glacier
Latitude: 59°46'12.00"N
Longitude: 150°13'15.00"W
Description
Style, Color
View
Altitude
Add link...
Add image...
Image URL:
OK
Cancel

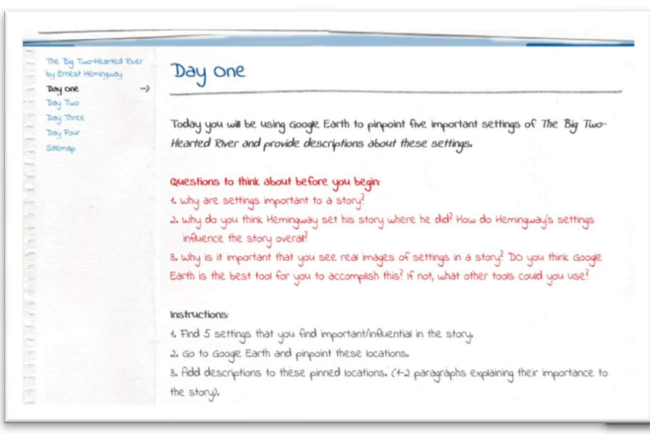
The McCarty Glacier in Alaska has been rapidly depleting in recent year. The debate about whether or not climate change is occuring is has come to an end, with the vast majority of scientists agreeing that our Earth is warming. Although the Earth having warming and cooling periods has been happening for millions of years, Scientists now argue that humans are having a major effect on the speed at which this temperature is increasing.
Over the past 200 years, the Industrial Revolution and the rapid increase in the burning of fossil fuels along with other factors such as deforestation, urbanization, and the production of greenhouse gases, have led to an increase in earths temperature. Our ozone layer is starting to develop
Pedersen Glacier
McCarty Glacier
Rugged Island
Chiswell Islands
Google earth

Riggs Glacier
Muir and Riggs Glaciers
2004
1941
The Riggs glacier in southern Alska used to have miles and miles of thick ice that covered the ground in between huge Alaskan mountains. Between the years of 1941 and 2004, the glaciers have retreated all the way back to the Muir Inlet, leaving behind a huge expanse of water, and also creating an area for vegetation to grow in places that were once covered in glacial ice. Nasa and other scientists have foundd that retreating glacies in southern Alska, such as the Riggs Glacier, may be opening the way for future earthquakes.
Directions: To here - From here
Google earth

APPENDIX 4.E

EXAMPLE OF A GROUP'S TEACHING WEBSITE

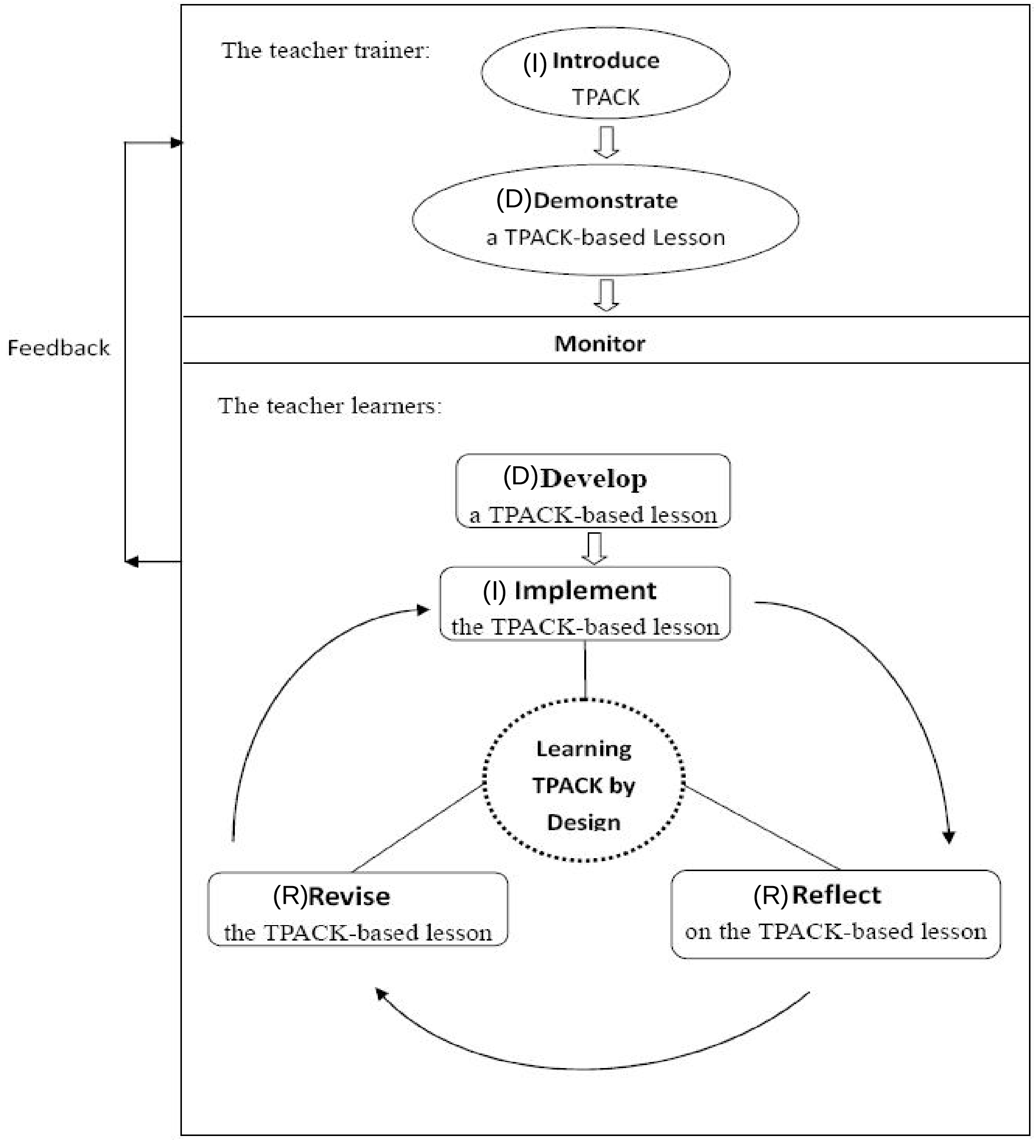

THE BIG TWO-HEARTED RIVER STUDENT SITE
Search this site
The Big Two-Hearted River by Ernest Hemingway
Day one
Day Two
Day Three
Day Four
Sitemap
The Big Two-Hearted River by Ernest Hemingway
Vision Three Images
Michael Koole 2008


The Big Two-Hearted River by Ernest Hemingway
Day one
Day Two
Day Three
Day Four
Sitemap
Day one
Today you will be using Google Earth to pinpoint five important settings of The Big Two-Hearted River and provide descriptions about these settings.
Questions to think about before you begin:
1. Why are settings important to a story?
2. Why do you think Hemingway set his story where he did? How do Hemingway's settings influence the story overall?
3. Why is it important that you see real images of settings in a story? Do you think Google Earth is the best tool for you to accomplish this? If not, what other tools could you use?
Instructions:
1. Find 5 settings that you find important/influential in the story.
2. Go to Google Earth and pinpoint these locations.
3. Add descriptions to these pinned locations. (1-2 paragraphs explaining their importance to the story).


1. Find 5 settings that you find important/influential in the story.
2. Go to Google Earth and pinpoint these locations.
3. Add descriptions to these pinned locations. (1-2 paragraphs explaining their importance to the story).
Google Earth link: www.earth.google.com.
You can find an example of pinpointed locations with descriptions on Google Earth here. Once you click on this link, click "Download" on the new page.
Lake Superior
ONTARIO (Canada)
Fox River
Seney
Two Hearted River
St. Ignace
MICHIGAN

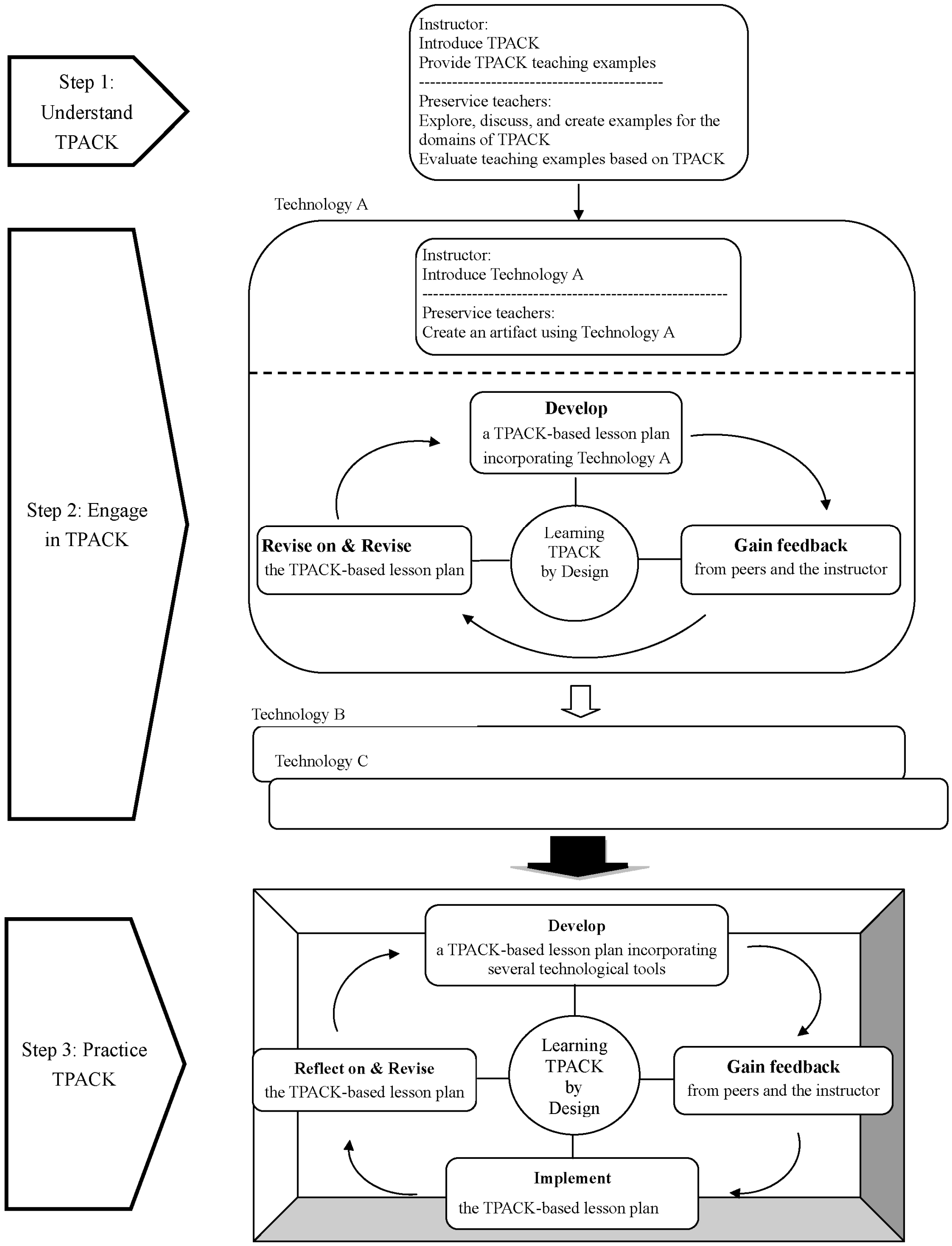
APPENDIX 5.A:

PROTOTYPE I OF THE TPACK-BASED ID MODEL (TPACK-IDDIRR)


The teacher trainer:
(I) Introduce
TPACK
(D)Demonstrate
a TPACK-based Lesson
Monitor
Feedback
The teacher learners:
(D)Develop
a TPACK-based lesson
(I) Implement
the TPACK-based lesson
Learning
TPACK by
Design
(R)Revise
the TPACK-based lesson
(R)Reflect
on the TPACK-based lesson

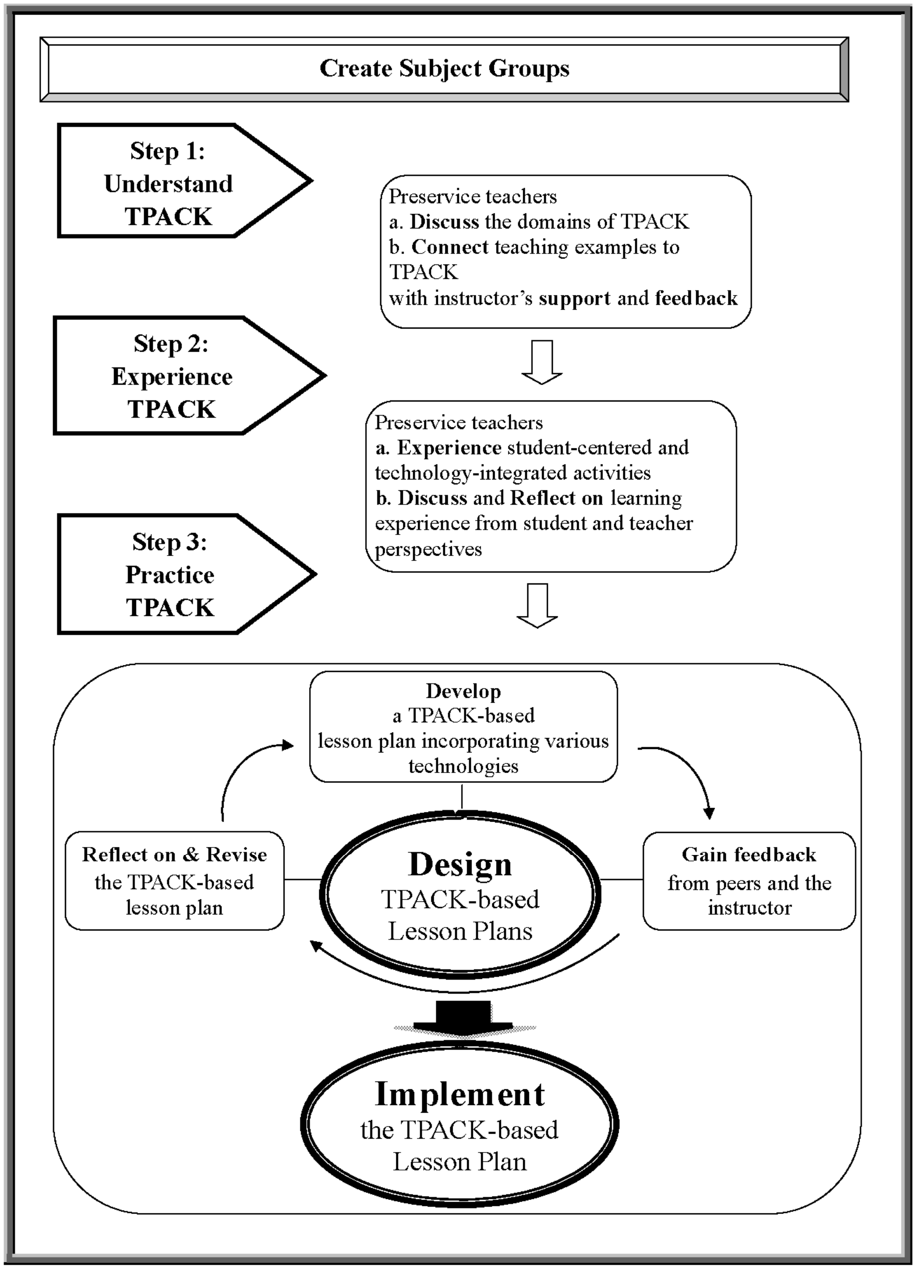
APPENDIX 5.B

PROTOTYPE II OF THE TPACK-BASED ID MODEL


Step 1: Understand TPACK
Instructor:
Introduce TPACK
Provide TPACK teaching examples
Preservice teachers:
Explore, discuss, and create examples for the domains of TPACK
Evaluate teaching examples based on TPACK
Step 2: Engage in TPACK
Technology A
Instructor:
Introduce Technology A
Preservice teachers:
Create an artifact using Technology A
Develop
a TPACK-based lesson plan incorporating Technology A
Revise on & Revise
the TPACK-based lesson plan
Learning TPACK by Design
Gain feedback
from peers and the instructor
Technology B
Technology C
Step 3: Practice TPACK
Develop
a TPACK-based lesson plan incorporating several technological tools
Reflect on & Revise
the TPACK-based lesson plan
Learning TPACK by Design
Gain feedback
from peers and the instructor
Implement
the TPACK-based lesson plan

APPENDIX 5.C

PROTOTYPE III OF THE TPACK-BASED ID MODEL


Create Subject Groups
Step 1: Understand TPACK
Preservice teachers
a. Discuss the domains of TPACK
b. Connect teaching examples to TPACK
with instructor's support and feedback
Step 2: Experience TPACK
Preservice teachers
a. Experience student-centered and technology-integrated activities
b. Discuss and Reflect on learning experience from student and teacher perspectives
Step 3: Practice TPACK
Develop a TPACK-based lesson plan incorporating various technologies
Reflect on & Revise the TPACK-based lesson plan
Design TPACK-based Lesson Plans
Gain feedback from peers and the instructor
Implement the TPACK-based Lesson Plan