A Mixed-Methods Examination of Influences on the Shape and Malleability of Technological Pedagogical Content Knowledge (TPACK) in Graduate Teacher Education Students

by

Kent Sabo

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved June 2013 by the
Graduate Supervisory Committee:

Robert Atkinson, Chair
Leanna Archambault
Wilhelmina Savenye

ARIZONA STATE UNIVERSITY

August 2013

ABSTRACT

Concerted efforts have been made within teacher preparation programs to integrate teaching with technology into the curriculum. Unfortunately, these efforts continue to fall short as teachers' application of educational technology is unsophisticated and not well integrated. The most prevalent approaches to integrating technology tend to ignore pedagogy and content and assume that the technology integration knowledge for all contexts is the same. One theoretical framework that does acknowledge content, pedagogy, and context in conjunction with technology is Technological Pedagogical Content Knowledge (TPACK) and was the lens through which teacher development was measured and interpreted in this study. The purpose of this study was to investigate graduate teacher education students' knowledge and practice of teaching with technology as well as how that knowledge and practice changes after participation in an educational technology course. This study used a mixed-methods sequential explanatory research design in which both quantitative and qualitative data were gathered from 82 participants. TPACK pre- and postcourse surveys were administered to a treatment group enrolled in an educational technology course and to a nonequivalent control group enrolled in a learning theories course. Additionally, pre- and postcourse lesson plans were collected from the treatment group. Select treatment group participants also participated in phone interviews. Analyses compared pre- and post-course survey response differences within and between the treatment and control groups. Pre- and postlesson plan rubric score differences were compared within the treatment group. Quantitative text analyses were performed on the collected lesson plans. Open and axial coding procedures were followed to analyze interview transcripts. The results of the study revealed five significant findings: 1) graduate students entering an educational technology course reported lower ability in constructs related to teaching with technology than in constructs related to teaching in a traditional setting; 2) TPACK was malleable and TPACK instruments were sensitive to that malleability; 3) significant gains in reported and demonstrated TPACK constructs were found after participating in an educational technology course; 4) TPACK construct ability levels vary significantly by participant characteristics; and 5) influences on teaching knowledge and practice range from internet resources, to mentor teachers, and to standardized curriculum packages.

DEDICATION

I dedicate my dissertation to my family for the relentless avalanche of support they heap on me through all my endeavors. I'm proud to follow in my father's academic footsteps and if I had my mother's work ethic, I would have finished this project a long time ago. I hope to pursue my goals with the commitment my brother has show in pursuit of his. I'm certain I haven't earned the pride my grandmother displays for me, but I might make up some ground with this degree.

ACKNOWLEDGMENTS

I would like to thank my dissertation committee for their expertise, encouragement, and guidance throughout my doctoral studies. I am indebted to my chair, Dr. Robert Atkinson, for giving me the opportunity to work on his lab's funded research projects and to help prepare grants when I was in a zone of proximal development (I knew just enough to be dangerous). It is due to my experiences working with him that I gained practical knowledge, skills, and abilities, which resulted in conference presentations, a book chapter, and a journal article. Dr. Leanna Archambault shaped my understanding of TPACK and introduced me to luminaries in the field. I am grateful for the access to her expertise, graduate students, and her TPACK instrument that made this dissertation possible. She is my model of a successful researcher in the field of technology and teacher education. Dr. Wilhelmina Savenye's expertise and instruction in educational evaluation helped pave the way to my current professional position. She is also the champion of every educational technology graduate student and I think many of us persist largely due to her encouragement.

I would also like to thank my partner, Dr. Laura Naumann, for her emotional support and her familiarity with academia. A partner that can help you keep the dream alive and has intimate knowledge of what it takes to make the dream a reality is truly invaluable. It is that unique combination that bolstered my belief that I could be successful in this business.

Finally, I would like to thank my educational technology program colleagues who have taken this journey with me. I developed lifelong friends and research collaborators and I appreciate all the advice, feedback, and words of encouragement that we shared.

TABLE OF CONTENTS

CHAPTER Page

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Chapter 1

INTRODUCTION

General Problem

Investment in educational technology infrastructure, training, and software continue to grow as some question the value of technology in education (Lemke, Coughlin, & Reifsneider, 2009). The expectations for how technology can and will transform education have long been high (Wellings & Levine, 2009). As far back as 1913 when motion picture projectors were first introduced in schools, Thomas Edison predicted, “Books will soon be obsolete in the schools. . . . It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in the next ten years” (as cited in Reiser, 2001, p. 55). Throughout the history of educational technology, proclamations like Edison's have made it difficult for the empirically measured effects of technology to stand up to outsized expectations (Reiser, 2001). Technologists and educators have been too confident that the significant institutional change required to reap the benefits of technology would be easily accomplished, and over time, there has been a lack of documentation on implemented technologies' impact on “student learning, teacher practice and system efficiencies” (Lemke et al., 2009, p. 5). Regardless of the lofty expectations and implementation issues, educational technology is contributing to student learning. In a meta-analysis of educational technology, researchers found that across the 15 types of technologies reviewed—from classroom response systems, to interactive whiteboards, and to virtual worlds—all have “primarily promising effects” on learning across content areas (Lemke et al., 2009, p. 7)

A lack of vision, access to research, leadership, teacher proficiency in integrating technology in learning, and professional development continue to be significant barriers to realizing the potential of currently implemented technologies for teaching and learning (Brown, 2006). Teachers need to know how to teach effectively with technology and are expected to do so prior to completing their teacher preparation program, despite the complex knowledge required for success (Hofer & Grandgenett, 2012). Furthermore, teachers are now expected to teach with technology by governmental and educational organizations through a variety of mandates and initiatives; however, studies have found that teachers do not use technology effectively in their teaching (Brown, 2006). Technologies are often used in ways that maintain existing practices in teaching, and it is most often used in computer education courses, vocational education, exploratory use in elementary school, and word processing (Brown, 2006). The lack of expertise in teaching with technology has been suggested as the limiting factor in the effectiveness of technology in teaching and learning, and teachers that have above-average technical skills and use computers for professional purposes teach with technology in more broad and sophisticated ways (Brown, 2006). This suggests that teacher preparation programs and in-service professional development programs are missing effective instruction and training in teaching with technology.

Concerted efforts have been made within teacher preparation programs to integrate teaching with technology into the curriculum. For example, the United States Department of Education announced the Preparing Tomorrow's Teachers to Use Technology grant program in 1999 and the program awarded more than 400 grants over five years, totaling $337.5 million (United States Department of Education). These efforts to integrate technology into teacher education programs continue to fall short as teachers' application of educational technology is unsophisticated and not well integrated (Brown, 2006; Harris, Mishra, & Koehler, 2009). Teachers are using technologies as “efficiency aids and extension devices” rather than “transformative devices” (Harris et al., 2009, p. 394). The majority of the most prevalent approaches to integrating technology into education are techno-centric in that they focus first on the affordances and constraints of the technologies and technological skill rather than on students’ learning needs. These prevalent approaches include: (a) software-focused initiatives; (b) demonstrations of sample resources, lessons, and projects; (c) technology-based educational reform efforts; (d) structured/standardized professional development workshops or courses and; (e) technology-focused teacher education courses (Harris et al., 2009). These five approaches tend to ignore pedagogy and content and assume that the technology integration knowledge for all contexts is the same. However, frameworks, practices, and pedagogical strategies vary across content areas such as science, literacy, and the arts. Approaches that do not account for these differences are limited in their effectiveness across different contexts. One theoretical framework that does acknowledge content, pedagogy, and context in conjunction with technology is Technological Pedagogical Content Knowledge (TPACK) and is the lens through which teacher development is measured and interpreted in this study (Harris et al., 2009).

Technological Pedagogical Content Knowledge (TPACK)

TPACK is a theoretical framework for understanding and describing the knowledge teachers require to effectively teach with technology and is the framework for this study (Mishra & Koehler, 2006). Mishra and Koehler (2006) defined TPACK as:

> The basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (p. 1029)

TPACK is an extension of Shulman's (1986) construct, Pedagogical Content Knowledge (PCK), which includes technology knowledge with content and pedagogical knowledge (Schmidt et al., 2009a). PCK describes the relationship between pedagogy (teaching strategies) and content (subject-matter knowledge) (Archambault & Barnett, 2010). PCK was developed by Shulman (1986) in response to the need for a theoretical framework that coherently explained the complex nature of teacher understanding and knowledge transmission. At the time he developed PCK, Shulman felt that educational research and policy had become too focused on pedagogy alone, to the detriment of content knowledge. He felt it was a mistake for education stakeholders to focus exclusively on generic teacher pedagogical practices like classroom management, lesson planning, and activity organization. Shulman was concerned that questions about the content teachers delivered, the questions they asked, and the explanations they provided were not being answered.

Initially, Shulman (1986) delineated three categories of content knowledge: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Content knowledge referred to the volume and organization of knowledge a teacher had in a particular content area. PCK was a type of content knowledge that “goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching,” and “that embodies the aspects of content most germane to its teachability” (Shulman, 1986, p. 9). Furthermore, he explained that PCK was knowledge of “the ways of representing and formulating the subject that make it comprehensible to others” (Shulman, 1986, p. 9). He distinguished PCK from the pedagogical knowledge of teaching, which included knowledge of the generic principles of teaching that had become the focus of much educational research. PCK is the type of knowledge that can distinguish between a content specialist and a teacher of that same content (Gess-Newsome, 1999). The third category of content knowledge, curricular knowledge, was knowledge of the programs and materials available to teach a certain subject and the characteristics of those programs and materials that make them suitable or unsuitable in a particular context (Shulman, 1986).

The following year, Shulman promoted PCK from a subcategory of content knowledge by including it as one of the seven knowledge bases for teaching (Gess-Newsome, 1999). The seven knowledge bases included “content knowledge, general pedagogical knowledge, curricular knowledge, knowledge of learners, knowledge of educational contexts, and knowledge of the philosophical and historical aims of education” (Gess-Newsome, 1999, p. 4). Grossman (1990), who was a former graduate student under Shulman, refined the seven knowledge bases into four bases that included: “general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge and knowledge of context” (p. 5). PCK was hypothesized to influence teachers' actions in the classroom the most among the four knowledge bases (Gess-Newsome, 1999).

Similar to Shulman (1986), Mishra and Koehler (2006) perceived an imbalanced focus within teaching and teacher education. They felt that teacher education and training as well as accepted teacher practices in teaching with technology focused only on the technology and not on how the technology was implemented. Within these systems, knowledge of technology is treated as separate from pedagogical and content knowledge. In the same way that PCK merged what were previously regarded as independent constructs (pedagogical knowledge and content knowledge), TPACK integrates knowledge of technology with knowledge of pedagogy and content. This framework suggests that simply adding technology to an educational context is inadequate and ineffective. A possible explanation for the techno-centric implementation of technology into teaching was the lack of a theoretical framework to guide implementation and understanding of the practice. Mishra and Koehler (2006) developed and refined TPACK over the course of five years by conducting design experiments to both understand and help develop teachers' effective use of technology. They contend that successful curriculum design is guided by theoretical frameworks that arrange learning and knowledge construction principles that serve as a foundation for a cogent and contextual learning experience (Mishra & Koehler, 2006). TPACK can serve as a framework for teacher knowledge, the design for instruction to enhance that knowledge, and a framework for research.

The TPACK framework includes three components of knowledge (technology, pedagogy, and content) and describes the interaction between the three components resulting in seven constructs displayed in Figure 1. The constructs include: technology knowledge, content knowledge, pedagogical knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. These constructs are defined as follows:

1. Technological knowledge (TK) is knowledge about various technologies.
2. Content knowledge (CK) is knowledge about subject matter.
3. Pedagogical knowledge (PK) is knowledge of teaching processes, methods, and strategies.
4. Pedagogical content knowledge (PCK) is knowledge of teaching processes, methods, and strategies for a specific subject matter.
5. Technological content knowledge (TCK) is knowledge of technology's ability to change how content is represented.
6. Technological pedagogical knowledge (TPK) is knowledge of how technologies can be used to teach.
7. Technological pedagogical content knowledge (TPACK) is knowledge of integrating technology into teaching a specific subject matter (Schmidt et al., 2009a).

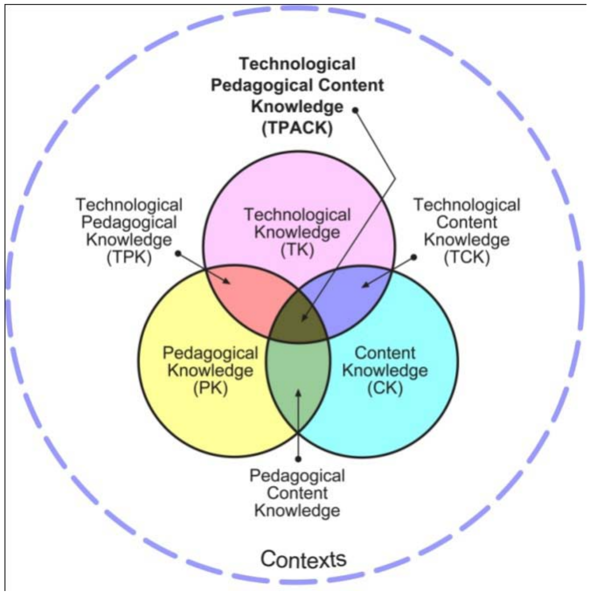

Figure 1: The TPACK framework. Reproduced by permission of the publisher, © 2012 by tpack.org.

TPACK Measurement

In assessing teachers' technology use, researchers have focused on teachers' attitudes and perceptions of and skills in using technology (Browne, 2009; Christensen & Knezek, 2009; Curts, Tanguma, & Pena, 2008; Franklin, 2007; Hogarty, Lang, & Kromrey, 2003; MacDonald, 2009). These measures gather important data but do not indicate teachers' knowledge specific to effective technology integration, nor do they measure teachers' practice. Instruments and methods that measure knowledge of effective teaching with technology are few, but the number is growing. Many of these instruments and methods were designed using the TPACK framework. Archambault and Crippen (2009) created a questionnaire to examine TPACK among kindergarten through twelfth grade (K-12) online educators, Schmidt et al. (2009a) created a questionnaire to measure TPACK in preservice teachers and Graham et al. (2009) created a questionnaire to examine the technology constructs within TPACK. Instruments that measure the practice of effective technology integration are even rarer. Harris, Grandgenett, and Hofer (2010) and Akcaoglu, Kereluik, and Casperson (2011) developed TPACK-based rubrics to assess technology-infused lessons and lesson plans. Kramarski and Michalsky (2010) used both a rubric and a self-report survey in their study of TPACK. The following researchers have also investigated TPACK through qualitative research: Groth, Spickler, Bergner, and Bardzell (2009) and Brantley-Dias, Kinuthia, Shoffner, de Castro, and Rigole (2007).

Survey instruments. Archambault and Crippen (2009) developed one of the first survey instruments to measure TPACK in K-12 online teachers. The development of the survey included two rounds of think-aloud pilots with online teachers and content validation through expert review. The root survey question asks respondents how they would rate their knowledge on various online teaching tasks. Item examples include, “my ability to create materials that map to specific district/state standards, my ability to distinguish between correct and incorrect problem solving attempts by students, and my ability to create an online environment which allows students to build new knowledge and skills” (Archambault & Crippen, 2009, p. 88).

Of the 1,795 online teachers who were sent the survey, 596 teachers from 25 states responded. Internal consistency measures for the survey's seven sub-scales ranged from 0.70 to 0.89. Archambault and Crippen (2009) found that the online teachers rated their knowledge of pedagogy, content, and pedagogical content the highest, which suggests that the teachers were confident in a variety of teaching strategies, creating materials, and planning the scope and sequence of topics. It also suggested that the teachers could recognize student misconceptions and judge students' problem solving techniques. The teachers reported knowledge levels dropped by 0.81 from pedagogy and content to technology. This suggested that the teachers were less confident with technology than with pedagogy and content. Respondents were confident in their traditional teacher knowledge but were less so when integrating technology. The researchers found that the correlations between TPACK constructs (pedagogy and content, pedagogical content and content, pedagogical content and pedagogy, technological content and technological pedagogy, technological pedagogical content and both technological pedagogy and technological content) were high, which suggested that the constructs may not be distinct or that the survey items were confounded (Archambault & Crippen, 2009).

Schmidt et al. (2009b) also developed an early TPACK survey instrument. The purpose of Schmidt et al.’s instrument was to measure preservice teachers' assessment of their TPACK. The researchers established content validity by reviewing the TPACK literature and had the items reviewed by experts. Participants in the survey development and validation study were 124 preservice teachers enrolled in an introductory instructional technology course. The course was purposely redesigned using TPACK as the course design framework. The majority of the participants were freshman (50.8%) female (93.5%) elementary education majors (79%) who had not completed their student teaching (85%) (Schmidt et al., 2009b). To measure the content areas taught by elementary teachers, the construct CK was separated into four sub-scales intended to measure content knowledge in mathematics, social studies, science, and literacy. Internal consistency for the survey's 10 sub-scales ranged from 0.75 to 0.92. To establish construct validity, the researchers performed two principal components analyses (PCA). After the first PCA, 28 items were eliminated from the survey. Individual PCAs were run on each of the seven TPACK constructs, and from each PCA a single factor structure emerged except for CK which had a four factor structure related to the four content areas within the sub-scale. Schmidt et al. (2009b) concluded that the results indicate an appropriate and reliable instrument for measuring TPACK in preservice teachers.

Graham et al. (2009) developed and tested a TPACK survey to measure the technology constructs TK, TPK, TCK and TPACK. The purpose of their study was to identify and measure TPACK in science instruction and to measure the change in TPACK confidence in participants. Content validity was established by basing the items on definitions and descriptions from the literature. Participants were 11 elementary teachers and four secondary teachers with teaching experience that ranged from 1 to 26 years. All the participants chose to participate in an intensive, eight day professional development program designed to improve their science teaching. The program also included an additional phase outside of the eight days in which teachers reflected on lessons implemented in the teachers' classroom. These teachers responded to the 31-item survey both before and after the program. Cronbach's alpha ranged from 0.91 to 0.95 for each of the sub-scales. Construct validity was not analyzed due to the small sample. Posttest surveys showed a significant increase for all measured TPACK constructs over the pretest survey. Effect sizes for these differences ranged from 0.55 to 0.85. Teachers pre- and posttest TK level was the highest followed by TPK, TPACK and TCK. TK is foundational to developing confidence in other technology TPACK domains. Low TCK scores may indicate confidence in using technologies designed to teach science rather than confidence in using technologies designed to do science. Open-ended responses suggest that teachers integrate technology using general teaching strategies rather than content-specific teaching strategies. The teachers' pedagogical use of technology was also higher than their students' pedagogical use of technology.

Rubrics. Harris et al. (2010) developed and validated a performance-based lesson plan rubric to evaluate TPACK. The researchers first developed a draft of the lesson plan rubric based on the TPACK theoretical framework. A draft of the rubric was sent to six TPACK researchers who gave feedback on the construct and face validity of the rubric. The developers then revised the rubric according to the feedback. Two groups of teachers (15 total teachers) who had technology integration experience were each asked to assess three technology-infused lesson plans created by preservice teachers. The 15 experienced teachers participated in a six-hour training to learn to use the rubric (Harris et al., 2010). The first group rated the lesson plans and provided feedback on the rubric, then the developers revised the rubric again after analyzing interrater reliability and internal consistency. Using the revised rubric, the second group of teachers rated the lesson plans and provided feedback. One month later, the teachers were asked to rescore the same three lesson plans in order to calculate the test and retest reliability of the rubric. The researchers found that the rubric had adequate reliability and validity and could be used by other researchers. Because the rubric was tested with preservice teachers' lesson plans, it may not be appropriate to evaluate experienced teachers' lesson plans. For rubric effectiveness, the planning documents (e.g., lesson plans) being evaluated need sufficient detail. Because teachers often do not write plans with enough detail, an interview protocol could be created to gather more data (Harris et al., 2010).

While the rubric developed by Harris et al. (2010) did not explicitly measure each of the seven TPACK constructs, one developed by Akcaoglu et al. (2011) does measure all seven TPACK constructs. Each of the constructs measured by the rubric includes two to three items rated on a five-point scale. The rubric grew out of a project in which the researchers were attempting to develop a coding scheme for lesson plans. The purpose for developing the rubric was to enable teacher educators to measure TPACK without the limitations of a self-report measure. Initially, the coding scheme was tested on two groups of preservice teachers enrolled in an educational technology course. The researchers compared results from rubric scores to scores from a self-report measure to validate the rubric. The rubric was further refined when the researchers evaluated publicly available lesson plans from the internet. From these lesson plan evaluations, the researchers found that interrater reliability between two raters was 0.88 (Akcaoglu et al., 2011).

Kramarski and Michalsky (2010) used both a rubric and a self-report survey to measure TPACK comprehension and design skills, and they self-regulated learning in two instructional treatments. The course included instructor-led discussions and summaries and student pairs practicing in a hypermedia environment. The content of the course focused on TPACK learning methods and implementations and pedagogical uses of computer tools. Ninety-five preservice secondary science teachers in Israel enrolled in a teacher education course on hypermedia design. Using an experimental design, the preservice teachers were randomly assigned to one of the two treatments. The two treatment groups were not statistically different in regard to demographics or any study variables. In one condition, students worked in pairs in a hypermedia environment. In the other condition, the same hypermedia environment was enhanced with metacognitive scaffolds (Kramarski & Michalsky, 2010). In the hypermedia with metacognitive treatment, the participants were exposed to self-questioning pop-ups within the hypermedia environment that addressed comprehension, connection, strategy, and reflection. Both the hypermedia condition and the hypermedia with metacognitive condition had 14 workshops lasting four hours each week supervised by two different teachers. Two measures of TPACK (comprehension skills and design skills) and two measures of self-regulated learning (aptitude and event) were administered at the beginning of the course and at the end of the course. The hypermedia with metacognitive group outperformed the hypermedia group on both measures of TPACK (Kramarski & Michalsky, 2010). The hypermedia with metacognitive group reported higher cognition, metacognition, and motivation than the hypermedia group and demonstrated the same characteristics on the self-regulated learning measures. There was a significant correlation between the two TPACK measures and the two self-regulated learning measures among all participants and within each treatment group. Higher correlations existed in the hypermedia with metacognitive group than in the hypermedia group. The results verified the hypotheses in that a hypermedia environment with metacognitive support is more effective in developing TPACK and fostering self-regulated learning than a hypermedia environment alone (Kramarski & Michalsky, 2010).

Qualitative methods. The purpose of the Groth et al. (2009) study was to investigate a method to assess TPACK in math teachers by evaluating the qualitative data gathered from lesson study cycles. Researchers used an *accounts of practice* method where researchers study classroom practice through the lens of a conceptual framework. The researchers applied the accounts of practice method during a lesson study professional development project. A lesson study involves a group of teachers, which create a lesson collaboratively. They then implement it, observe the implementation, and then gather to debrief. The researchers observed and gathered data from a group of math teachers teaching systems of equations using graphing calculators within a lesson study framework. Data sources included written lesson plans from the teachers, a faculty member's reviews of the lessons, transcripts and videos of implemented lessons, and the recordings and transcripts of debriefing sessions about the implemented lessons (Groth et al., 2009). After the data were gathered, the researchers created a case study database and then inferences about teachers' TPACK were drawn from the data. Inferences were validated and refined among the researchers. Inferences included: (a) the need for teachers to develop knowledge on how to compare multiple representation and solution strategies with the graphing calculator; (b) teachers needed to avoid representing the calculator as a black box and; (c) teachers needed to develop and present problems that reveal the calculator's limitations (Groth et al., 2009). The model the researchers used to gather and evaluate the data within the TPACK framework for this study does not provide a way to measure individual teacher TPACK; however, the ability to capture reasoning of the group is a strength of the model. The exploratory potential of the model is also a strength because researchers can generate plausible ideas for psychometric assessment items (Groth et al., 2009). The model captures the fluid, contextually situated, collective development of teacher knowledge. The model is also flexible and can be used in many different settings. Finally, the model draws upon the expertise of a variety of people (Groth et al., 2009).

Employing a case study design, Brantley-Dias et al. (2007) explored how using case-based instructional strategies promotes Pedagogical Technology Integration Content Knowledge (PTICK) development. PTICK is the researchers' particular variation of

TPACK. Participants in the study were enrolled in an alternative teaching licensure program. Nineteen participants were part of a science education cohort and 14 were part of an English education cohort. All participants had content area degrees, but only four had provisional teaching certificates and one year of teaching experience. All participants were enrolled in the Technology for Educators course. The Technology for Educators course was a problem-centered, activity-based course. It addressed the National Educational Technology Standards for Teachers (NETS-T) and the Interstate New Teacher Assessment and Support Consortium (INTASC) standards (Brantley-Dias et al., 2007). Three of the researchers were either instructors for the course or the course designer. The participants analyzed cases appropriate to their content area from course materials. Students answered questions about the cases and provided a group report. Individual reflections on the cases were submitted. Each participant analyzed a total of four cases and submitted responses and reflections. Participants also submitted course reflections at the beginning, middle, and end of the course (three total reflections). Researchers used content analysis to categorize concepts while ideas and pattern matching within and across cases were used to answer research questions (Brantley-Dias et al., 2007). Researchers found that students felt more prepared to integrate technology as the course progressed and demonstrated increasing technology integration conceptual knowledge. Students also made connections between the technology course, their content courses and their pedagogy courses. Researchers observed that case studies and group discussions allowed reflection on how students would handle the situation in the case study. Case studies provide preservice teachers an opportunity to reflect and discuss planning instruction even without previous teaching experience and allow students to recognize value in communities of practice. The researchers concluded that case-based instruction promotes PTICK development (Brantley-Dias et al., 2007).

TPACK Criticism

Since Mishra and Koehler's (2006) seminal article that described the TPACK framework, the theory has enjoyed widespread acceptance in educational research and, to a lesser extent, in teacher education (Cox, 2008). There are some researchers and educators who have expressed concerns with the theoretical development of TPACK as the focus of TPACK research has been mostly concerned with the description of the framework (Graham, 2011).

Despite considerable work on the descriptive value of TPACK, the framework and its technology-related constituent parts do not have widely accepted and precise definitions (Graham, 2011). In a conceptual analysis of TPACK, Cox (2008) found 89 definitions of TPACK in the literature as well as 13 definitions of TCK and 10 definitions of TPK. The lack of clarity in the TPACK framework may partially lie in PCK, its foundational theory, which was developed by Shulman (1986). Though PCK has produced much useful research, the complexity of the concept does not lend itself to clear and discriminant definitions that are easily researched (Baxter & Lederman, 1999; Gess-Newsome, 1999).

The continued popularity of both PCK and TPACK may be due to the intuitive nature of the components (Graham, 2011). The constituent parts of pedagogical knowledge and content knowledge in PCK and the addition of technological knowledge for TPACK are instinctual and evident to many educators who recognize the importance of the interplay among these knowledge areas (Graham, 2011). While the individual components of the two frameworks are clear and discrete, it is where the components overlap to create complex new concepts (TPK, PCK, TCK, TPACK) that the issues arise.

In an exploratory factor analysis of an early TPACK instrument, Archambault and Barnett (2010) found that they were unable to extract all seven TPACK constructs from the data resulting from 596 responses of online educators. The researchers extracted three factors: pedagogical content knowledge, technological-curricular content knowledge, and technological knowledge (Archambault & Barnett, 2010). This result suggests that either the seven TPACK components are not defined discretely enough to be measured, or that none of the seven the components exist in practice.

TPACK does have descriptive value, but it is a complex framework that currently lacks theoretical clarity and precise construct definitions. TPACK research and theory development is in its relative infancy as it began in earnest following Mishra and Koehler's (2006) seminal article. TPACK's faults do not call for abandonment of the framework, but rather more diligent research that may lead to a clear and precise theory.

Graduate Teacher Education

The majority of the current methods to measure TPACK are developed for use within specific contexts with specific teacher types. For example, Archambault and Crippen (2009) created their survey to examine TPACK among K-12 online educators while Schmidt et al. (2009a) created their survey to measure TPACK in undergraduate preservice teachers. The fact that these two TPACK questionnaires were designed for use with such specific populations highlights the importance of studying both teacher and teacher education subgroups. Undergraduate preservice teachers and in-service teachers as participants are featured in the bulk of studies on technology in teacher education.

Comparatively few studies focus on graduate education students. For the purposes of this study, graduate teacher education students are defined as those who are pursuing an advanced teaching degree either while currently teaching in a K-12 environment or with the intention to pursue a career in teaching at that level. In a search of the Education Resources Information Center, only 13 results emerged from a search for the terms *graduate teacher education* and *technology*. Similarly, a search of the Association for the Advancement of Computing in Education's Education and Information Technology Digital Library returned a list of 10 articles with the search term *graduate teacher education*. Specific to TPACK, two articles investigated TPACK in a graduate education context (Hofer & Grandgenett, 2012; Machado, Laverick, & Smith, 2011).

Although graduate students may be underrepresented in educational technology research, they represent a significant population within teacher education. Statistics reveal that 49.5% of all teachers have some postbaccalaureate work, while 42.8% have earned a master's degree (Aud et al., 2011). Because many states now require their teachers to earn a graduate degree to reach the highest level of licensure, the number of teachers seeking a graduate education is only likely to increase (United States Department of Education, 2011). Graduate students in education are therefore a significant and important subgroup to investigate.

Overview of Present Study

The purpose of this study was to investigate graduate teacher education students' knowledge and practice of teaching with technology as well as how that knowledge and practice changes after participation in an educational technology course. This study used a mixed-methods sequential explanatory research design that required two phases. First, quantitative data was collected and analyzed. Then qualitative data was collected. The datasets from the two phases were connected, integrated, and interpreted to answer the questions of the study (Ivankova, Creswell, & Stick, 2006). A mixed-methods study requires an overarching mixed research question along with subquestions related to the different phases of the study (Tashakkori & Creswell, 2007). The overarching mixed question for this study was: what is the shape and malleability of TPACK among graduate teacher education students enrolled in an educational technology course? Answering this question required measurement of the preliminary shape of TPACK, analysis of how that shape changed at the end of the semester, and inquiry into TPACK influences outside of the course. Malleability in this study is defined as a property of a measured characteristic and that characteristic's susceptibility to change or fluctuation over time (Keenan & Evans, 2009). In contrast, stability of a measured characteristic is typified by its consistency over time.(Caspi, Roberts, & Shiner, 2005). This study also aimed to answer the following subquestions:

1. What is the level of TPACK, reported and demonstrated, among graduate teacher education students?
2. Do TPACK levels, reported and demonstrated, change after participation in an educational technology course?
3. Are self-reported levels of TPACK evident in artifacts of teacher practice?
4. How does the language differ between artifacts developed before the course and artifacts developed at the end of the course?
5. How do students with higher levels of TPACK differ from those with lower levels of TPACK?

6. What teaching and learning experiences influenced students' knowledge of and practice in teaching?

Mixed methods. Two definitive characteristics of mixed-methods studies are the collection and analysis of both qualitative and quantitative data and the integration of the two data types to more comprehensively answer research questions (Creswell & Plano Clark, 2011). There are many reasons for gathering the two types of data. The multiple data sets provide an opportunity for triangulation among the data for corroboration and provide additional explanatory possibilities as one data set can help explain the result of the other. The addition of qualitative data also provides context to quantitative data, and the combination offers a more comprehensive view of the studied phenomenon (Creswell & Plano Clark, 2011). Mixed-methods researchers have documented over 40 mixed methods designs and the sequential explanatory design was a popular design that has been used in social and behavioral science research (Ivankova et al., 2006). Limitations of the design include the lengthy amount of time required and the feasibility of collecting both types of data (Ivankova et al., 2006)

Priority of the quantitative or qualitative phase depends on the researcher's interests, the study's audience, and the emphasis of the study. However, the quantitative phase is generally given priority in sequential explanatory designs. Integration is the stage in the research process where the mixing of methods occurs. This can include developing both quantitative and qualitative research questions at the outset of the study and integrating the results of the two datasets and interpreting them together at the end of the study. In sequential explanatory designs, the two datasets are also connected. The results of one phase inform the data collection in the following phase. This connection can manifest in the selection of participants and the development of data collection protocols for the qualitative phase based on the results from the quantitative phase. Finally, the results are presented jointly in the discussion section by first answering the quantitative and qualitative questions, then using the qualitative data to explain the quantitative results (Ivankova et al., 2006).

This study collected quantitative data from a survey and from lesson plans and qualitative data through interviews. Priority was given to the quantitative phase because that phase was designed to answer the majority of the research questions. The qualitative and quantitative data were connected at two points in the study. Using the connecting strategy as described by Creswell and Plano Clark (2011), quantitative results determined the strategies used to collect qualitative data, including how participants were selected and how the interview protocols were developed. The second point of interface was during interpretation. A mixed-method design was appropriate for this study because eliminating either the quantitative data or the qualitative would result in an incomplete view of TPACK among graduate students.

Previous research suggested that measuring TPACK using a self-report measure alone may be inadequate (Archambault & Barnett, 2010). Beyond the complexity of measuring a construct like TPACK is the inherent limitations of self-report measures. Self-report instruments ask participants questions that measure knowledge, attitudes, and practices and rely on answers based on the participants' perception of the truth (Schwarz & Sudman, 1994). In addition to issues of perception, cognitive psychologists warn of the fallibility of human memory (Schacter, 1999). Further, Cook and Campbell (1979) reported that participants tend to report what they think researchers want to see, or they respond in ways that reflect positively on their abilities and knowledge. Due to the complexities of measuring TPACK and the limitations of self-report measures, a mixed-methods design featuring multiple strategies and analyses to minimize potential error and maximize the meaning of data was chosen (Tashakkori and Teddlie, 2003).

Philosophical assumptions. The philosophy most associated with mixed-methods research is pragmatism. Pragmatism is a philosophy that “draws on many ideas, including employing 'what works,' using diverse approaches, and valuing both objective and subjective knowledge” (Creswell & Plano Clark, 2011, p. 43). According to Tashakkori and Teddlie (2003), no fewer than 13 researchers have selected pragmatism as the best philosophy for mixed-methods research. The pragmatic researcher is primarily focused on his research questions rather than specific methods. He therefore selects the methods deemed appropriate for answering the research questions whether or not they are traditionally aligned with competing philosophical views like postpositivism or constructivism (Creswell & Plano Clark, 2011).

As Creswell and Plano Clark (2011) suggested, it is preferable to select philosophical assumptions based the phases of research design. The quantitative phase of the study was based on an empirical measure of the specific constructs of TPACK using a survey and rubric instrument; because of the basis, the study is set in a postpositivist philosophy. The philosophical assumptions shift as one enters into the qualitative phase. In interviewing teachers, the researcher gained individual perspectives and practices related to TPACK. Honoring individual participant responses to gain deeper understanding and explanatory power is more in line with a constructivist philosophy (Creswell & Plano Clark, 2011). Rather than confining the work with one view of the world, the researcher takes advantage of two philosophies—postpositivism in the quantitative phase, then constructivism in the qualitative phase—that enabled the research questions to be answered more thoroughly.

Chapter 2

METHOD

Participants

The study participants were graduate education students (*n* = 82) enrolled in education courses at a large university in the southwest who were working toward their education graduate degrees during the Fall 2011 and Spring 2013 semesters. One participant group was enrolled in an educational technology course (the treatment group) and the other participant group was enrolled in a learning theory course (the nonequivalent control group). The majority of the graduate students enrolled in these courses were current or former kindergarten through twelfth grade (K-12) teachers.

The treatment group participants in this study included 57 master's-level graduate education students enrolled in an educational technology integration course at a large southwestern university who were working toward their graduate degrees in educational technology or accomplished teaching. Most (68%) were enrolled in the course because it was a required course in their program. Only 23% of participants stated that they were enrolled in the course because the topic of the course was of personal interest to them. The majority of the participants were female (*n* = 45) and there were 12 male participants. More than half were between the ages of 21 and 29 (58%), while 23% were between 30 and 39 years old. The remaining 19% of participants were over 40 years old.

The majority of the participants were current or former teachers (83%) with an average of 5.3 years of experience. Of those who were current or former teachers, 34% taught in elementary schools, 36% taught in middle schools, and 15% taught in high schools. There were also participants who taught in higher education contexts (15%).

Most participants described their knowledge of educational technology as intermediate (68%), while 21% responded that they were beginners, and 11% responded that they were advanced. No participants responded that their knowledge of educational technology was at the expert level.

When participants responded to statements that described their current level of classroom technology use on the presurvey, 33% responded that technology served as a supplement to their existing curriculum, 22% responded that they had a lack of access to technology or a lack of time to pursue implementation of technology, and 18% responded that their use of technology occurred outside of their classroom in a lab environment. In addition, 16% responded that they integrated technology to enrich understanding of concepts, themes and processes, and to solve authentic problems.

The control group in this study was made up of 26 graduate student participants enrolled in a learning theories course at a large southwestern university. All but one of the students were pursuing education-related graduate degrees with the majority (85%) pursuing a master's degree. Most of the control group participants were female (n = 16) while there were 10 male participants. Less than half were between the ages of 21 and 29 (42%), while 23% were between 30 and 39 years old. The remaining 35% of participants were over 40 years old.

Over half (58%) of the participants were current or former teachers with an average of 4.6 years of teaching experience. Of those who were current or former teachers, 23% taught in elementary schools, 4% taught in middle schools, and 8% taught in high schools. There were also participants who taught in higher education contexts (19%) and one participant who worked in corporate training. Most participants described their educational technology knowledge level as either beginner (42%) or intermediate (39%). The remainder described their level of knowledge as advanced (19%). No participants responded that their knowledge of educational technology was at the expert level.

Power Analysis

Schmidt et al. (2009b) developed a TPACK self-report instrument for use with preservice teachers. They tested the instrument with the students in an introductory instructional technology course. The researchers administered the survey to the students during the first week of the semester and again during the final week of the semester. The researchers reported means and standard deviations for the pre- and posttest administrations, which could be used to calculate effect size statistic Cohen's *d*. Among the instrument's 10 subscales, *d* ranged from 0.33 to 1.44 with an average of 0.68. While this study was not a replication of Schmidt et al. (2009b), their effect sizes provide a frame of reference for the current study's power analysis. Using the power analysis software G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to determine an appropriate sample size for the study, specifically research question 2, Table 1 was created. The power calculations were based on the dependent samples *t*-test statistic. Cohen (1988) determined that a *d* value of 0.20 was a small effect, 0.50 a medium effect and 0.80 a large effect. With a conservative estimate based on the Schmidt et al. (2009b) smallest effect size of 0.33 and power at 0.80, the estimated sample size required was 59. With a medium effect size of 0.50, which is less than the mean effect size from the reference study, the estimated sample size required was 27.

Table 1

Sample Size Estimate Results from a Power Analysis for Dependent Samples

Power	Population *d*		
	0.20	0.50	0.80
0.70	120	21	9
0.80	156	27	12
0.90	216	36	15

Note. Alpha = 0.05

Educational Technology Course

The treatment group's course is a 15-week, 500-level, online educational technology course that focuses on effective methods for integrating digital technology into teaching to assist learning. The course investigates uses of digital technology in classrooms, creating learning environments rich with technology, and implementing instructional design principles in the design and development of technology-based materials for learning. Coverage of topics includes learning theory, instructional software, productivity software, hyper and multimedia, assistive technology, and technology integration in various content areas. The course follows a mastery learning approach where learning units are organized by week and are followed by formative assessment, individualized feedback, and additional opportunities to meet mastery assessment levels, if necessary (Bloom, 1968). The course objectives are based on some of the National Educational Technology Standards for Teachers (NETS-T) developed by the International Society for Technology in Education (ISTE). Specifically they are:

III. Teaching, Learning and the Curriculum

Teachers implement curriculum plans that include methods and strategies for applying technology to maximize student learning. Teachers:

A. facilitate technology-enhanced experiences that address content standards and student technology standards.

B. use technology to support learner-centered strategies that address the diverse needs of students.

C. apply technology to develop students' higher order skills and creativity.

D. manage student learning activities in a technology-enhanced environment (International Society for Technology in Education, 2000, p. 1).

In addition to weekly readings from Integrating Educational Technology into Teaching (Roblyer & Doering, 2009) and other resources, students engaged in a variety of instructional activities to meet the objectives of the class. Sample assignments are described below.

- Educational technology rationale: Students prepared a rationale for integrating technology in education supported by evidence from empirical research.
- Educational software reviews: In small groups, students wrote detailed reviews of educational software, categorized by software type, that they might use in their classroom. The categories included drill and practice, tutorial, simulation, games, and problem solving.
- Productivity tool lesson plan and model: Students wrote a lesson plan that integrated productivity software. They also designed a model that demonstrated the outcomes of the lesson. The plan met at least one of the following criteria: based on real-world problems; scaffolds and tools enhanced learning; provided opportunities for feedback, reflection, and revisions; and build local and global

learning communities.

- Google spreadsheet activity: Students designed an instructional activity that facilitated inquiry, problem solving, or decision making in the student's content area.
- Assistive technology: Students identified and described an instructional technology that failed to meet accessibility standards. Students addressed the impact that the inaccessible technology could have in the classroom and provided suggestions for how to remedy the issues with the technology.
- Choose your own adventure (COYA) website: Students designed and developed an instructional website using the COYA framework. For example, a COYA site could be based on a story of scientific discovery or a sequence of historical or future events that requires users to make decisions based on the content of the website.

Learning Theory Course

The control group was enrolled in a 15-week, 500-level course that focused on psychology's historical view of learning over the preceding century. The course is largely lecture and discussion based, relying on students to complete regular readings from "Psychology of Learning for Instruction" (Driscoll, 2004), "The Structure of Scientific Revolutions" (Kuhn, 1970), and other selected articles. The topics of the course included the following.

- Philosophical foundations
- Science, paradigms, and foundations of learning theory
- Behaviorism and alternate approaches

- Verbal learning and information processing
- The developmental perspective
- The role of emotion, attention, and pattern recognition
- Network and schema representations
- The neurobiological perspective

Assessment is based on two essay-based exams and three projects. The projects include a written summary and oral presentation of research on learning theory, a summary of a “Learning and the Brain” conference session, and participation in a book study and discussion group based on one of three books.

Instruments and Data Sets

Questionnaire. Archambault and Crippen's (2009) questionnaire was designed to measure TPACK in K-12 online educators. The questionnaire includes 24 items with seven subscales each related to the seven Technological Pedagogical Content Knowledge (TPACK) constructs. The researchers conducted two rounds of think-aloud pilots where teacher participants were asked to explain what they were thinking while they answered the survey questions. These pilots allowed the researchers to demonstrate construct validity of the questionnaire. Experts in educational technology and online education were asked to review the questionnaire to establish content validity. The Cronbach alpha coefficient ranged from 0.70 to 0.89 for each subscale in the questionnaire (Archambault & Crippen, 2009). The root question for each of the 24 items is, “How would you rate your own ability in doing the following tasks associated with teaching in a distance education setting?” (Archambault & Crippen, 2009, p. 88). Response options range from Poor to Excellent on a 5-point, Likert-type scale. Each of the seven subscales includes three to four items designed to measure TPACK constructs: content (e.g., “My ability to create materials that map to specific district/state standards”), pedagogy (e.g., “My ability to determine a particular strategy best suited to teach a specific concept”), technology (e.g., “My ability to assist students with troubleshooting technical problems with their personal computers”), technological content (e.g., “My ability to implement district curriculum in an online environment”), technological pedagogy (e.g., “My ability to create an online environment which allows students to build new knowledge and skills”), content pedagogy (e.g., “My ability to distinguish between correct and incorrect problem solving attempts by students”), and technological pedagogical content knowledge (e.g., “My ability to create an online environment which allows students to build new knowledge and skills”) (Archambault & Crippen, 2009, p. 88). The survey requests that participants rate their ability on each item so that their responses serve as a proxy for participant practice. Research suggests that teacher knowledge and teacher practice are closely related (Cochran-Smith & Lytle, 1999). In other words, teacher knowledge is evident in teacher practice. This close relationship allows researchers to measure practice with a theory based on knowledge (Dawson, Ritzhaupt, Liu, Rodriguez & Frey, in press).

Prior to administration to the two groups of participants in this study, eight items in the questionnaire were minimally modified to address the teaching experience among the participants. The minor modifications would eliminate online teaching language and replace it with language appropriate to face-to-face teaching. For example, item T was changed from “My ability to implement district curriculum in an online environment” to “My ability to implement district curriculum in a technology-rich environment” and item X was changed from “My ability to meet the overall demands of online teaching” to “My ability to meet the overall demands of teaching effectively in the 21st century" (Archambault & Crippen, 2009, p. 88). The survey also included demographic items that requested information like gender, age, grade level taught, years of teaching experience, and content area taught.

Rubric. The TPACK lesson plan rubric emerged from a project by Kereluik, et al. (2010) in which they developed a coding scheme for lesson plans. The purpose for creating the coding scheme was to provide teacher educators a tool to assess preservice teachers' TPACK through artifacts rather than self-report measures. Preliminary coding schemes were developed by examining lesson plans from a summer preservice educational technology course while the final coding scheme was refined by examining lesson plans collected from 11 preservice teachers in a different educational technology course. To validate the coding scheme, the researchers compared the results from the coding with results from the TPACK self-report measure developed by Schmidt et al. (2009a) (Kereluik, Casperson, & Akcaoglu, 2010). From this coding scheme, a rubric was developed using "theory-driven thematic coding" (Akcaoglu, Kereluik, Casperson, 2011, p. 4261) and construct analysis of both the theory and a TPACK self-report instrument developed by Schmidt et al. (2009a). The initial rubric included measures of TK, TPK, TCK, PK, PCK and TPACK. The original rubric was refined in a second project when the researchers assessed STEM lesson plans made available online by companies like Hewlett Packard, Intel, and Microsoft. To establish interrater reliability, 12 lesson plans were randomly chosen and rated by two researchers. Cronbach's alpha for interrater reliability was 0.88 while the intraclass correlation coefficient was 0.74 for a single researcher and 0.85 for the average of the two researchers. The remaining lesson plans were coded individually. Redundant items were removed from the rubric and an item to assess lesson plan objectives was added (Akcaoglu et al., 2011). Each of the seven TPACK constructs includes between two and three items that were rated on a five-point scale. Some items were edited for clarity prior to scoring lesson plan for this study. Representative items include:

> (CK) Provides clear lesson objectives; (PK) Assessments are aligned with the objectives and instructional strategies; (TK) Provides rationale for technology choice; (PCK) Presents appropriate strategies for developing understanding of the subject content; (TPK) Chooses technologies enhancing student learning; (TCK) Link between technology and content is obvious or explicit; (TPCK) Technology enhances content objectives and instructional strategies. (Akcaoglu et al., 2011, p. 4262)

Lesson plans. Two lesson plans were requested from each participant. The first lesson plan was one that the participant prepared prior to enrolling in the course that included a technology component. The second lesson plan was the product of the final assignment for the educational technology course. For this final assignment, participants were asked to develop, implement, and evaluate an original lesson that demonstrated effective teaching with technology. The lesson included the following sections: Introduction, Rationale, Activity Description, Lesson Evaluation, and Conclusions. The Rationale section included the participant's theoretical perspective, the target population, technology standards, content standards, and the instructional goals of the lesson. The Activity description included the instructional objectives and a description of the activity and procedures. Participants were required to address cultural connections and considerations for learners with special needs.

Interviews. Select participants were interviewed based on their responses to the precourse survey—a key process in the sequential explanatory design. Interview questions included: 1) Can you tell me what a typical lesson looks like in your classroom? 2) What are some of the most effective teaching methods that you use? 3) What were some of the influences or resources that helped you gain your knowledge in your specific content/subject area? 4) What are your opinions about the use of technology in teaching? 5) Describe an early instance where you saw an effective use of technology in teaching. 6) Describe the first time you taught with technology. 7) What has influenced the use of technology in your teaching? The full interview script is in included in Appendix C.

Procedure

Quantitative phase. Both groups of participants were asked to respond to the modified TPACK survey. The treatment group responded to the pre- and postsurvey during the Fall 2011 semester. The control group responded to the pre- and postsurvey during the Spring 2013 semester. The groups accessed the link to the survey from their course learning management system or from an email sent by the researcher. The survey was delivered and responses collected by an online survey service. The students completed the survey in the first week of the courses so their responses were not influenced by the content of the course. The participants progressed through the content and activities of their courses over the following 15 weeks. Prior to the end of the semester, the groups were asked to respond again to the same survey.

The treatment group was also asked to provide two lesson plans. Although these artifacts could be considered qualitative data, they were analyzed quantitatively by assigning rubric scores and using text analysis software. The first lesson plan that participants provided was one that they developed before the beginning of their technology integration course and that features the use of technology. They were instructed to upload a lesson plan to their course management system at the beginning of the Fall 2011 semester. As a project required for the course, the participants developed an original lesson plan that featured the use of technology and demonstrated their understanding of educational theory and met appropriate standards from the National Educational Technology Standards. This lesson plan was uploaded to the course management system at the end of the Fall 2011 semester.

Lesson plans were scored using the TPACK rubric by external raters who had experience and expertise in both teaching and educational technology. External raters were used to eliminate potential researcher bias. The raters were not informed about the design nor whether the lesson plans they rated were created before or after the course. The raters were each given a rater guide which included directions on how to score the lesson plans, a TPACK primer, and construct definitions. Lesson plans from participants who submitted both a pre- and postcourse lesson plan were scored by two raters. One pair of raters rated the precourse lesson plans and one pair of raters rated the postcourse lesson plans. The intraclass correlation coefficient for the precourse lesson plan raters was 0.79. The coefficient for the postcourse lesson plan raters was 0.82. These coefficients suggest acceptable interrater reliability (Shrout & Fleiss, 1979). The rater scores were then averaged for each rubric item for analysis. With coefficients that suggested acceptable interrater reliability, a single rater scored the lesson plans from participants who submitted either a precourse or postcourse lesson plan.

Qualitative phase. Sequential, mixed-methods study designs call for engaging in what Creswell and Plano Clark (2011) described as connected mixed-methods data analysis. In this study, the qualitative data was first connected to the quantitative data through the purposeful interview sample based on presurvey responses and the TPACK-related interview questions. Creation of a joint display, a table which arrays both quantitative and qualitative data so that the two data sources can be directly compared, was the second connection (Creswell & Plano Clark, 2011, p. 412).

In the qualitative phase, 11 participants were selected based on their responses to the precourse survey. Selected participants' precourse TPACK scores ranged from high to low and these participants were arranged into a high scoring group, a mid scoring group and a low scoring group. The grouping allowed investigations into the differences among high, middle, and low scoring participants. Upon selection, participants were asked to participate in phone interviews, which were conducted during the Fall 2012 semester.

Chapter 3

RESULTS

Quantitative survey and rubric data involving Technological Pedagogical Content Knowledge (TPACK) were analyzed using both descriptive and inferential statistics with statistical software package SPSS 20. Text analysis for the lesson plan artifacts was processed by the LIWClite7 (Pennebaker, Booth, & Francis, 2007) and the KH Coder 2 (Higuchi, 2012) software programs. Qualitative interview and open-ended written response data were analyzed using the qualitative analysis software package HyperRESEARCH 3.5. See Table 2 for a summary of the research questions and analytic approaches.

Table 2

Research Questions and Analytic Approaches

Research Question	Data Set	Analysis
1. What is the level of TPACK, reported and demonstrated, among graduate teacher education students?	TPACK survey scores TPACK rubric scores	Descriptive
2. Do TPACK levels, reported and demonstrated, change after participation in an educational technology course?	TPACK survey scores TPACK rubric scores	Dependent-samples *t* test One-way analysis of variance Regression
3. Are self-reported levels of TPACK evident in artifacts of teacher practice?	TPACK rubric scores	Correlations Bivariate regression
4. How does the language differ between artifacts developed before the course and artifacts developed at the end of the course?	Lesson plans	Automated text analysis
5. How do students with higher levels of TPACK differ from those with lower levels of TPACK?	TPACK survey scores Interview transcripts	Analysis of variance Regression Inductive data analysis

6. What teaching and learning experiences influenced students' knowledge of and practice in teaching?	Interview transcripts	Qualitative coding Inductive data analysis

TPACK Levels

The analyses in this section were conducted to answer the question: What is the level of TPACK, reported and demonstrated, among graduate teacher education students?

Treatment group survey. Participants (*n* = 57) responded to a 19-item presurvey designed to measure their perceived TPACK ability. Internal consistency estimates of reliability were computed for each of the survey's seven subscales: PK (0.81), CK (0.82), TK (0.88), PCK (0.84), TPK (0.84), TCK (0.80), and TPACK (0.69). These estimates indicate satisfactory reliability (Kline, 2000). Mean scores were highest on items related to producing lesson plans (3.75), using a variety of teaching strategies (3.55), and planning the sequence of concepts taught (3.53). Mean scores were lowest on the items related to encouraging interactivity using technology (2.41), moderating web-based student interactivity (2.44), and using technology to predict student' skills (2.61). See Table 3 for the remaining mean item scores on the presurvey. TPACK construct scores were calculated from the presurvey items and participant mean scores were highest in PCK (3.40) and PK (3.36). Mean construct scores were lowest in TPK (2.64) and TK (2.78). See Table 4 for the remaining mean construct scores from the presurvey.

Table 3

Mean TPACK Presurvey Item Scores

Item	Scale	Treatment *M*	Treatment *SD*	Control *M*	Control *SD*
Vary teaching strategies	PK	3.55	0.74	3.05	1.16
Adjust method based on student performance	PK	3.44	0.77	3.05	1.19
Determine strategy for concept.	PK	3.27	0.93	3.05	1.05
Plan sequence of concepts	CK	3.53	0.91	3.30	1.08
Scope of concepts	CK	3.47	0.88	3.33	1.20
Materials map to standards	CK	3.25	0.89	2.70	1.17
Address software issues	TK	2.98	0.90	3.30	0.98
Troubleshoot hardware	TK	2.71	1.02	3.10	1.00
Assist students with technology troubleshooting	TK	2.66	1.01	3.10	1.17
Produce lessons with topic appreciation	PCK	3.75	0.84	3.11	1.10
Assist students in noticing concept connections	PCK	3.43	0.82	3.10	1.02
Anticipate student topic misconceptions	PCK	3.31	0.81	2.85	0.93
Distinguish correct problem solving attempts	PCK	3.27	0.78	3.05	1.10
Use technological representations	TCK	3.09	1.00	3.40	0.94
Implement district curriculum with tech	TCK	3.00	0.90	2.50	1.19
Use web-based courseware/applications	TCK	2.69	0.84	2.90	1.02
Implement technology to support teaching methods	TPK	2.79	0.99	2.55	1.00
Students build knowledge/skills with technology	TPK	3.00	0.83	2.81	0.98
Moderate web-based student interactivity	TPK	2.44	0.88	2.65	1.23
Encourage student interactivity technology	TPK	2.41	1.01	2.40	0.99
Use results of tech-based assessments.	TPCK	3.13	0.88	2.75	0.91
Meet demands of 21st century	TPCK	2.89	0.85	3.00	1.11

teaching					
Create effective representations with technology	TPCK	2.86	0.88	2.75	1.25
Predict students' topic skill/understanding with technology	TPCK	2.61	0.82	2.68	1.16

Note. Treatment *n* = 57. Control *n* = 25.

Table 4

Mean TPACK Presurvey Construct Scores

Construct	Treatment *M*	Treatment *SD*	Control *M*	Control *SD*
PK	3.36	0.72	3.08	1.01
TK	2.78	0.88	3.14	0.96
CK	3.37	0.75	3.14	0.98
PCK	3.40	0.67	3.05	0.89
TCK	2.89	0.78	2.93	0.86
TPK	2.64	0.75	2.62	0.84
TPACK	2.85	0.61	2.77	0.97

Note. Treatment *n* = 57. Control *n* = 25.

Participants (*n* =39) responded to the same 19 items in a postsurvey. Internal consistency estimates of reliability were computed for each of the survey's seven subscales: PK (.085), CK (0.87), TK (0.90), PCK (0.88), TPK (0.87), TCK (0.84), and TPACK (0.83). These estimates indicate satisfactory reliability (Kline, 2000). Mean scores were highest on items related to producing lesson plans (3.90), planning the sequence of concepts taught (3.87), and deciding on the scope of concepts taught (3.87). Mean scores were lowest on the items related to troubleshooting hardware technical problems (2.82), encouraging interactivity using technology (3.00), and assisting students with troubleshooting technical problems (3.05). See Table 5 for the remaining mean item scores on the postsurvey. Construct scores were calculated from the postsurvey items and participant mean scores were highest in CK (3.85) and PK (3.68). Mean construct scores were lowest in TK (2.99) and TPK (3.23). See Table 6 for the remaining mean construct scores on the post-survey.

Table 5

Mean TPACK Postsurvey Item Scores

Item	Sub	Treatment M	Treatment SD	Control M	Control SD
Vary teaching strategies	PK	3.85	0.93	3.24	1.04
Determine strategy for concept	PK	3.62	0.78	3.15	0.88
Adjust method based on student performance	PK	3.59	0.85	3.20	0.95
Materials map to standards	CK	3.82	1.05	2.70	1.38
Scope of concepts	CK	3.87	1.06	3.33	1.02
Plan sequence of concepts	CK	3.87	0.95	3.35	1.18
Troubleshoot hardware	TK	2.82	1.12	3.10	1.14
Address software issues	TK	3.10	1.02	3.35	1.14
Assist students with technology troubleshooting	TK	3.05	1.15	2.95	1.23
Distinguish correct problem solving attempts	PCK	3.56	0.85	3.45	0.94
Anticipate student topic misconceptions	PCK	3.51	0.76	3.25	0.91
Produce lessons with topic appreciation	PCK	3.90	0.88	3.47	0.90
Assist students in noticing concept connections	PCK	3.69	0.73	3.35	0.88
Use technological representations	TCK	3.67	0.90	3.40	0.88
Implement district curriculum with tech	TCK	3.54	0.82	3.00	1.08
Use web-based courseware/applications	TCK	3.26	0.94	3.15	0.99
Students build knowledge/skills with technology	TPK	3.44	0.79	3.33	1.02
Implement technology to support teaching methods	TPK	3.49	0.91	2.95	1.10
Moderate web-based student interactivity	TPK	3.16	1.10	2.90	0.91
Encourage student interactivity	TPK	3.00	1.01	2.75	1.07

technology					
Use results of tech-based assessments	TPCK	3.26	0.99	2.90	1.17
Predict students' topic skill/understanding with technology	TPCK	3.13	0.91	2.74	0.93
Create effective representations with technology	TPCK	3.65	0.68	3.15	0.88
Meet demands of 21st century teaching	TPCK	3.45	0.83	3.26	0.81

Note. Treatment *n* = 57. Control n = 25.

Table 6

Mean TPACK Postsurvey Construct Scores

Construct	Treatment *M*	Treatment *SD*	Control *M*	Control *SD*
PK	3.68	0.75	3.17	1.01
TK	2.99	1.00	3.11	1.10
CK	3.85	0.91	3.11	1.01
PCK	3.67	0.69	3.35	0.77
TCK	3.49	0.77	3.18	0.78
TPK	3.23	0.82	2.96	0.88
TPACK	3.28	0.77	3.02	0.74

Note. Treatment *n* = 57. Control *n* = 25.

Control group survey. Participants (*n* = 25) responded to a 19-item presurvey designed to measure their perceived TPACK ability. Internal consistency estimates of reliability were computed for each of the survey’s seven subscales: PK (0.85), CK (0.79), TK (0.91), PCK (0.89), TPK (0.79), TCK (0.74), and TPACK (0.89). These estimates indicate satisfactory reliability (Kline, 2000). Mean scores were highest on items related to using content-specific technological representations (3.40), planning the sequence of concepts taught (3.35), and deciding on the scope of concepts (3.33). Mean scores were lowest on the items related to encouraging student interactivity using Web 2.0 tools (2.40), implementing district curriculum with technology (2.50), and implementing technologies to support different teaching methods (2.55). See Table 3 for the remaining mean item scores on the pre-survey. TPACK construct scores were calculated from the presurvey items and participant mean scores were highest in CK (3.14) and TK (3.14). Mean construct scores were lowest in TPK (2.62), and TPACK (2.77). See Table 4 for the remaining mean construct scores from the presurvey.

Participants (*n* =21) responded to the same 19 items in a postsurvey. Internal consistency estimates of reliability were computed for each of the survey's seven subscales: PK (0.87), CK (0.82), TK (0.95), PCK (0.87), TPK (0.89), TCK (0.71), and TPACK (0.89). These estimates indicate satisfactory reliability (Kline, 2000). Mean scores were highest on items related to producing lesson plans that demonstrate topic appreciation, (3.47), distinguishing appropriate problem solving attempts by students (3.45), and using content-specific technological representations (3.40). Mean scores were lowest on the items related to creating materials that map to standards (2.70), using technology to predict student skill/understanding (2.74), and encouraging interactivity among students with technology (2.75). See Table 5 for the remaining mean item scores on the postsurvey. TPACK construct scores were calculated from the postsurvey items and participant mean scores were highest in PCK (3.35) and TCK (3.18). Mean construct scores were lowest in TPK (2.96) and TPACK (3.02). See Table 6 for the remaining mean construct scores from the postsurvey.

Lesson plan rubric scores. Treatment group participants (*n* = 35) submitted a lesson plan that integrated technology and was developed before the course. Internal consistency estimates of reliability were computed for each of the survey's seven subscales: PK (0.83), CK (0.93), TK (0.93), PCK (0.94), TPK (0.89), TCK (0.95), and

TPACK (0.98). These estimates indicate satisfactory reliability (Kline, 2000). Mean scores were highest on items related to evidence of content knowledge (3.50), providing clear objectives (3.40), and meaningful and relevant content (3.29). Mean scores were lowest on the items related to providing rationale for technology choice (1.59), providing rationale for delivering instruction with technology (1.71), and demonstrating understanding of technology (2.04). See Table 7 for the remaining mean item scores from the prelesson plan rubric. TPACK construct scores were calculated from the prelesson plan rubric items and participant mean scores were highest in CK (3.45) and PK (3.17). Mean construct scores were lowest in TPK (1.96) and TK (1.98). See Table 8 for the remaining mean construct scores from the precourse rubric.

Table 7

Mean TPACK Prelesson Plan Rubric Item Scores

Item	Construct	*M*	*SD*
Aligned assessments objectives & strategies	PK	3.04	1.35
Lesson organizes/manages student behavior	PK	3.04	1.19
Content is meaningful and relevant	PK	3.14	0.90
Provides clear lesson objectives	CK	3.29	0.90
Evidence of content knowledge	CK	3.50	1.19
Lesson plan incorporates technology	TK	2.31	1.16
Provides rationale for technology	TK	1.59	1.04
Demonstrates understanding of technology	TK	2.04	1.13
Effective/appropriate teaching strategies	PCK	3.19	1.03
Awareness of student misconceptions	PCK	2.17	1.11
Appropriate strategies for content	PCK	3.09	1.10
Method enhancing technology	TPK	2.07	1.18
Student centered technology	TPK	2.10	1.13
Rationale for technology choice to deliver instruction	TPK	1.71	1.05
Appropriate technologies for subject	TCK	2.53	1.19
Explicit link between technology and content	TCK	2.36	1.27
Uses content, pedagogy, and technology strategies in concert	TPACK	2.34	1.10
Technology enhances content and strategies	TPACK	2.33	1.18

Table 8

Mean TPACK Prelesson Plan Rubric Construct Scores

Construct	*M*	*SD*
PK	3.17	1.00
CK	3.45	1.24
TK	1.98	1.04
PCK	2.81	1.02
TPK	1.96	1.00
TCK	2.44	1.20
TPACK	2.34	1.12

Treatment group participants (*n* = 41) also submitted a lesson plan as a final project for the educational technology course. Those lesson plans were scored using the same TPACK rubric and same method as with the precourse lesson plans. Internal consistency estimates of reliability were computed for each of the survey's seven subscales: PK (0.76), CK (0.61), TK (0.91), PCK (0.87), TPK (0.61), TCK (0.84), and TPACK (0.89). These estimates indicate questionable to satisfactory reliability (Kline, 2000). Mean scores were highest on items related to choosing student-centered technologies (3.68), choosing content appropriate technologies (3.57), and incorporating technology (3.65). Mean scores were lowest on items related to awareness of possible student misconceptions (2.29), organization and procedures for managing student behavior (2.65), and presenting appropriate learning strategies for the content (3.01). See Table 9 for the remaining mean item scores from the postlesson plan rubric. TPACK construct scores were calculated from the postlesson plan rubric items and participant mean scores were highest in TK (3.49) and TCK (3.43). Mean construct scores were lowest in PCK (2.84) and PK (2.95). See Table 10 for the remaining mean construct scores from the postcourse rubric.

Table 9

Mean TPACK Postlesson Plan Rubric Item Scores

Item	Construct	*M*	*SD*
Aligned assessments objectives and strategies	PK	2.91	1.12
Lesson organizes/manages student behavior	PK	2.65	0.96
Content is meaningful and relevant	PK	3.29	0.76
Provides clear lesson objectives	CK	2.82	1.11
Evidence of content knowledge	CK	3.45	0.82
Lesson plan incorporates technology	TK	3.65	0.73
Provides rationale for technology	TK	3.35	1.14
Demonstrates understanding of technology	TK	3.48	0.97
Effective/appropriate teaching strategies	PCK	3.22	0.89
Awareness of student misconceptions	PCK	2.29	0.86
Appropriate strategies for content	PCK	3.01	0.95
Method enhancing technology	TPK	3.22	0.77
Student centered technology	TPK	3.68	0.80
Rationale for technology choice to deliver instruction	TPK	3.23	1.11
Appropriate technologies for subject	TCK	3.57	0.79
Explicit link between technology and content	TCK	3.28	1.18
Uses content, pedagogy, and technology strategies in concert	TPACK	3.07	1.02
Technology enhances content and strategies	TPACK	3.01	1.13

Table 10

Mean TPACK Prelesson Plan Rubric Construct Scores

Construct	*M*	*SD*
PK	2.95	.79
CK	3.13	.83
TK	3.49	0.89
PCK	2.84	0.80
TPK	3.38	0.68
TCK	3.43	0.94
TPACK	3.04	1.02

TPACK Change

The analyses in this section were conducted to answer the question: Do TPACK levels, reported and demonstrated, change after participation in an educational technology course?

Treatment group survey. Mean difference survey scores were calculated for participants who responded to both the pre- and postcourse survey (n = 38). Mean difference scores (presurvey minus postsurvey) were highest on items related to implementing technology to support teaching methods (0.84), using technology to create effective representations (-0.83), and moderating web-based student interactivity (-0.81). Mean difference scores were lowest on items related to producing lesson plans (-0.11), adjusting teaching based on student performance (-0.13), and troubleshooting software issues (-0.16). Construct mean difference scores were highest in TPK (-0.68) and TCK (-0.67). Construct mean difference scores were lowest in PK (-0.25) and PCK (-0.26). Table 11 includes the remaining item and construct mean difference scores.

Paired-samples *t*-tests were conducted for each of the survey items and each of the survey subscales to evaluate differences between pre- and postsurvey item and subscale scores. Results indicate that postsurvey scores were significantly higher than presurvey scores for each of the survey subscales. Results also indicated that postsurvey scores were significantly higher than presurvey scores for 19 of the 24 survey items. The standardized effect size index (d) ranged from small (0.35) to large (1.14) for significant mean differences. This suggests small to large changes in TPACK constructs after participating in an educational technology course. Table 11 displays mean differences, standard deviations, effect sizes, and p-values for each of the survey items and constructs.

Table 11

Item and Construct Mean Difference from Treatment Group Pre- to Postsurvey

Construct/Item	Pre to Post *M*	*SD*	*d*	*p*
PK	-0.25	0.57	0.45	0.01
Vary teaching strategies	-0.26	0.72	0.36	0.03
Determine strategy for concept	-0.37	0.85	0.43	0.01
Adjust method based on student performance	-0.13	0.88	0.15	0.36
CK	-0.39	0.59	0.67	0.00
Materials map to standards	-0.45	0.86	0.52	0.00
Scope of concepts	-0.37	0.94	0.39	0.02
Plan sequence of concepts	-0.27	0.77	0.35	0.04
TK	-0.30	0.70	0.43	0.01
Troubleshoot hardware	-0.18	0.90	0.21	0.21
Address software issues	-0.16	0.82	0.19	0.24
Assist students with technology troubleshooting	-0.55	0.95	0.58	0.00
PCK	-0.26	0.58	0.44	0.01
Distinguish correct problem solving attempts	-0.32	0.90	0.35	0.04
Anticipate student topic misconceptions	-0.26	0.76	0.35	0.04
Produce lessons with topic appreciation	-0.11	0.73	0.14	0.38
Assist students in noticing concept connections	-0.27	0.77	0.35	0.04
TCK	-0.67	0.59	1.14	0.00
Use technological representations	-0.63	0.82	0.77	0.00
Implement district curriculum with technology	-0.66	0.67	0.98	0.00
Use web-based courseware/applications	-0.68	0.82	0.83	0.00
TPK	-0.68	0.75	0.91	0.00
Students build knowledge/skills with technology	-0.55	0.89	0.62	0.00
Implement tech to support teaching methods	-0.84	1.00	0.84	0.00
Moderate web-based student interactivity	-0.81	0.97	0.84	0.00
Encourage student tech interactivity	-0.70	0.97	0.73	0.00

TPACK	-0.45	0.74	0.61	0.00
Use results of technology-based assessments	-0.24	1.02	0.23	0.16
Predict students' topic skill/understanding with technology	-0.51	1.15	0.45	0.01
Create effective representations with technology	-0.83	0.85	0.99	0.00
Meet demands of 21st century teaching	-0.57	0.73	0.78	0.00

Control group survey. Paired-samples *t*-tests were conducted for each of the survey items and each of the survey subscales to evaluate differences between pre- and postsurvey item and subscale scores. Participants scored significantly higher on the postsurvey on the item related to distinguishing appropriate problem solving attempts by students, $t(19) = -2.18$, $p = 0.04$, and on the item related to building student knowledge and skills with technology, $t(20) = -2.23$, $p = 0.04$. Participants also scored significantly higher on the postsurvey subscales associated with those two items: PCK, $t(20) = -2.47$, $p = 0.02$ and TPK, $t(20) = -2.17$, $p = 0.04$. The remaining item and construct scores were not significantly different from pre- to postsurvey. These results suggest that the control group's scores increased from pre- to postsurvey in PCK and one associated item as well as in TPK and one associated item. Table 12 displays mean differences, standard deviations, effect sizes, and *p*-values for each of the survey items and constructs.

Nine participants in the control group responded that they were enrolled in one or more educational technology courses during the semester the pre- and postsurveys were administered. Paired-samples *t*-tests were conducted for each of the survey items and constructs, excluding participants who were enrolled in an educational technology course. All tests were nonsignificant including tests for item and construct scores that were significantly different in the full control group sample. The item related to distinguishing appropriate problem solving attempts by students was not significant, $t(13) = -0.90$, $p = 0.39$, and the item related to building student knowledge and skills with technology was also not significant, $t(14) = -0.94$, $p = 0.36$. In addition, PCK scores, $t(14) = -1.10$, $p = 0.29$, and TPK scores, $t(14) = -1.44$, $p = 0.17$ were not significantly different from pre- to postsurvey. These results suggest that the item and construct scores did not change from pre- to postsurvey for participants in the control group who were not enrolled in an educational technology course ($n = 15$).

Table 12

Item and Construct Mean Difference from Control Group Pre- to Postsurvey

Construct/Item	Pre to Post *M*	*SD*	*d*	*p*
PK	-0.09	0.85	0.10	0.64
Vary teaching strategies	-0.19	0.98	0.19	0.38
Determine strategy for concept	-0.10	0.72	0.14	0.54
Adjust method based on student performance	-0.15	1.23	0.12	0.59
CK	0.03	0.83	0.04	0.86
Materials map to standards	0.00	0.92	0.00	1.00
Scope of concepts	0.00	1.05	0.00	1.00
Plan sequence of concepts	-0.05	1.10	0.05	0.84
TK	0.03	0.67	0.05	0.83
Troubleshoot hardware	0.00	0.95	0.00	1.00
Address software issues	-0.05	0.69	0.07	0.75
Assist students with technology troubleshooting	0.15	0.93	0.16	0.48
PCK	-0.31	0.57	0.54	0.02
Distinguish correct problem solving attempts	-0.40	0.82	0.49	0.04
Anticipate student topic misconceptions	-0.40	0.88	0.45	0.06
Produce lessons with topic appreciation	-0.37	0.83	0.44	0.07
Assist students in noticing concept	-0.25	0.79	0.32	0.17

connections				
TCK	-0.25	0.79	0.31	0.18
Use technological representations	0.00	0.92	0.00	1.00
Implement district curriculum with technology	-0.50	1.19	0.42	0.08
Use web-based courseware/applications	-0.25	1.16	0.21	0.35
TPK	-0.35	0.73	0.47	0.04
Students build knowledge/skills with technology	-0.52	1.08	0.49	0.04
Implement technology to support teaching methods	-0.40	1.14	0.35	0.13
Moderate web-based student interactivity	-0.25	1.16	0.21	0.35
Encourage student technology interactivity	-0.35	0.93	0.38	0.11
TPACK	-0.25	0.89	0.28	0.22
Use results of technology-based assessments	-0.15	1.09	0.14	0.55
Predict students' topic skill/understanding with technology	-0.05	1.13	0.05	0.84
Create effective representations with technology	-0.40	1.14	0.35	0.13
Meet demands of 21st century teaching	-0.26	0.81	0.33	0.17

Welch Analysis of Variance ANOVA *F*-tests were conducted to evaluate differences in TPACK presurvey construct scores between the treatment group and the control group. The independent variable had two levels: treatment and control. The dependent variables were the seven TPACK constructs. None of the tests were significant. These results suggest that the scores on the seven TPACK constructs from the treatment group did not differ significantly from the scores from the control group. Table 13 displays *F*-statistics, degrees of freedom, and *p*-values for each of the construct tests.

Table 13

Treatment and Control Group Presurvey Construct Score Differences

Construct	Welch's F	$df1$, $df2$	p
PK	0.67	1, 39.37	0.42
CK	0.71	1, 42.62	0.41
TK	1.61	1, 43.59	0.21
PCK	1.84	1, 40.96	0.18
TCK	0.61	1, 47.98	0.44
TPK	0.00	1, 45.39	0.95
TPACK	0.02	1, 34.71	0.89

Lesson plan rubric scores. Mean difference rubric scores were calculated for participants who submitted both the precourse and final project lesson plan (n = 28). Mean difference scores (precourse score minues final project score) were highest on items related to choosing student-centered technologies (-1.48), providing a rationale for technology choice (-1.39), and incorporating technology in lesson plans (-1.30). Mean difference scores were lowest on items related to including aligned objectives and instructional strategies (0.00), demonstrating awareness of student misconceptions (-0.11), and selecting effective teaching strategies (-0.13). TPACK construct mean difference scores were also calculated and were highest in TK (-1.30) and TPK (1.28). Mean difference construct scores were lowest in PCK (0.01) and PK (0.24). Table 14 includes the remaining item and construct mean difference scores.

Paired-samples t-tests were conducted for each of the rubric items and each of the rubric subscales to evaluate differences between pre- and postcourse rubric item and subscale scores. Results indicate that postcourse rubric scores were significantly higher than precourse rubric scores for each of the technology-related rubric subscales (TK, TPK, TCK, and TPACK). Results also indicated that postcourse rubric scores were significantly higher than precourse rubric scores for 11 of the 18 rubric items. The standardized effect size index (*d*) ranged from medium (0.50) to large (1.38) for significant mean differences. This suggests medium to large changes in TPACK constructs after participating in an educational technology course. Table 14 displays mean differences, standard deviations, effect sizes, and *p*-values for each of the rubric items and constructs.

Table 14

Item and Construct Mean Difference from Pre- to Postcourse Rubric

Construct/Item	M (Pre - Post)	SD	d	P
PK	0.24	1.01	0.24	0.21
Aligned assessments objectives and strategies	0.00	1.19	0.00	1.00
Lesson organizes/manages student behavior	0.66	1.21	0.55	0.01
Content is meaningful and relevant	0.07	1.10	0.06	0.73
CK	0.31	1.28	0.24	0.21
Provides clear lesson objectives	0.41	1.39	0.29	0.13
Evidence of content knowledge	0.21	1.27	0.17	0.38
TK	-1.30	1.04	1.26	0.00
Lesson plan incorporates technology	-1.30	0.98	1.32	0.00
Provides rationale for technology	-1.39	1.23	1.13	0.00
Demonstrates understanding of technology	-1.21	1.17	1.03	0.00
PCK	0.01	1.04	0.01	0.95
Effective/appropriate teaching strategies	-0.13	1.26	0.10	0.60
Awareness of student misconceptions	-0.11	1.04	0.10	0.59
Appropriate strategies for content	0.27	1.08	0.25	0.20
TPK	-1.28	1.05	1.21	0.00
Method enhancing technology	-1.30	1.36	0.96	0.00
Student centered technology	-1.48	1.08	1.38	0.00

Rationale for technology choice to deliver instruction	-1.05	1.26	0.84	0.00
TCK	-0.84	1.11	0.76	0.00
Appropriate technologies for subject	-1.04	1.01	1.03	0.00
Explicit link between technology and content	-0.64	1.30	0.50	0.01
TPACK	-0.64	1.12	0.57	0.01
Uses content, pedagogy, and technology strategies in concert	-0.61	1.07	0.56	0.01
Technology enhances content/strategies	-0.68	1.23	0.55	0.01

Survey and Rubric Construct Score Correlations

The analyses in this section were conducted to answer the question, "Are self-reported levels of TPACK evident in artifacts of teacher practice?"

Construct score correlations across instruments. Correlation coefficients were computed between the seven TPACK subscales from the survey and the seven TPACK subscales from the rubric. The results from the presurvey and precourse rubric score correlation analyses presented in Table 15 show that only one of the correlations (survey PK with rubric TCK) was significant. The results from the postsurvey and postcourse rubric score correlation analyses presented in Table 16 show that only three of the correlations (rubric TK with survey PK, CK, and PCK) were significant. These results suggest that the TPACK subscales from the survey instrument may not measure the same constructs as the TPACK subscales from the rubric instrument.

Table 15

Presurvey with Precourse Rubric Correlations

		Survey						
	Construct	PK	TK	CK	PCK	TPK	TCK	TPACK
Rubric	PK	-0.193	-.0241	-0.118	-0.254	-0.227	-0.172	-0.152
	TK	0.321	-0.245	0.210	0.149	-0.022	0.218	0.130
	CK	-0.090	-0.240	0.046	-0.185	-0.193	-0.041	-0.004
	PCK	-0.224	-0.306	-0.109	-0.258	-0.266	-0.216	-0.215
	TPK	0.252	-0.214	0.138	0.135	0.049	0.234	0.201
	TCK	0.375*	-0.164	0.159	0.237	0.080	0.286	0.230
	TPACK	0.319	-0.169	0.111	0.236	0.067	0.248	0.171

Note. n = 32. * $p < 0.05$ ** $p < 0.01$

Table 16

P*ostsurvey with Postcourse Rubric Correlations*

		Survey						
	Construct	PK	TK	CK	PCK	TCK	TPK	TPACK
Rubric	PK	0.030	-0.088	0.221	0.079	0.192	0.090	0.081
	TK	0.340*	0.057	0.385*	0.343*	0.327	0.162	0.332
	CK	-0.010	0.055	0.073	0.113	0.132	0.003	0.037
	PCK	0.016	-0.127	0.139	0.110	0.063	-0.079	0.043
	TCK	0.144	-0.158	0.235	0.145	0.143	-0.029	0.126
	TPK	0.218	0.071	0.266	0.267	0.303	0.082	0.310
	TPACK	0.153	-0.056	0.288	0.174	0.256	0.091	0.178

Note. n = 34. * $p < 0.05$ ** $p < 0.01$

Construct score correlations within instruments. Correlation coefficients were computed among the seven TPACK constructs on the pre- and postsurvey. The results of the presurvey correlation analyses presented in Table 17 show that 15 out of 21 correlations were statistically significant and were greater than or equal to 0.28. The results of the postsurvey correlation analyses presented in Table 18 show that 20 out of the 21 correlations were statistically significant and were greater than or equal to 0.34. The results suggest that the survey instrument may not adequately discriminate among the seven TPACK constructs.

Table 17

Presurvey Construct Correlations

Construct	PK	TK	CK	PCK	TPK	TCK	TPACK
PK	1						
TK	-0.009	1					
CK	0.674**	-0.050	1				
PCK	0.770**	0.062	0.710**	1			
TPK	0.190	0.522**	0.253	0.425**	1		
TCK	0.281*	0.406**	0.325*	0.456**	0.747**	1	
TPACK	0.486**	0.262	0.477**	0.638**	0.669**	0.827**	1

Note. *n* = 56. * p < 0.05 ** p < 0.01

Table 18

Postsurvey Construct Correlations

Construct	PK	TK	CK	PCK	TCK	TPK	TPACK
PK	1						
TK	0.276	1					
CK	0.881**	0.344*	1				
PCK	0.882**	0.369*	0.836**	1			
TCK	0.649**	0.582**	0.734**	0.705**	1		
TPK	0.515**	0.584**	0.600**	0.559**	0.827**	1	
TPACK	0.655**	0.558**	0.671**	0.661**	0.790**	0.779**	1

Note. *n* = 39. * p < .05 ** p < .01

Correlation coefficients were computed among the seven TPACK constructs on the pre- and postcourse rubric scores. The results of the precourse rubric score correlation analyses presented in Table 19 show that 15 out of 21 correlations were statistically significant and were greater than or equal to 0.36. The results of the postcourse rubric score correlation analyses presented in Table 20 show that 21 out of the 21 correlations were statistically significant and were greater than or equal to 0.39. The results suggest that the rubric instrument may not adequately discriminate among the seven TPACK constructs.

Table 19

Precourse Rubric Construct Correlations

Construct	PK	TK	CK	PCK	TPK	TCK	TPACK
PK	1						
TK	0.467**	1					
CK	0.750**	0.334	1				
PCK	0.765**	0.361*	0.698**	1			
TPK	0.442**	0.946**	0.314	0.414*	1		
TCK	0.425*	0.898**	0.309	0.257	0.845**	1	
TPACK	0.463**	0.896**	0.303	0.292	0.856**	0.962**	1

Note. n = 35. * p < .05 ** p < .01

Table 20

Postcourse Rubric Construct Correlations

Construct	PK	TK	CK	PCK	TCK	TPK	TPACK
PK	1						
TK	0.499**	1					
CK	0.746**	0.385*	1				
PCK	0.728**	0.509**	0.606**	1			
TCK	0.638**	0.649**	0.441**	0.609**	1		
TPK	0.511**	0.872**	0.434**	0.602**	0.579**	1	
TPACK	0.717**	0.650**	0.528**	0.576**	0.882**	0.631**	1

Note. n = 41. * p < .05 ** p < .01

Lesson Plan Content

The analyses in this section were conducted to answer the question: How does the language differ between artifacts developed before the course and artifacts developed at the end of the course? Matching pre- and postlesson plans ($n = 28$) were analyzed for word count, standard linguistic dimensions (e.g., pronouns, articles, and verbs), words related to psychological processes (e.g., cognitive, affective, and social), and personal concerns (e.g., work, achievement, and leisure) with the LIWClite7 text analysis software. Paired-samples *t*-tests were then conducted for each of the word categories to evaluate differences between pre- and postlesson plan word usage. In addition to word count, significant differences were found the following categories: verbs (walk, went, see), social processes (talk, share, they), affective processes (happy, cry, abandon), positive emotion (love, nice, sweet), cognitive processes (cause, know, ought), and achievement (earn, hero, win). Postlesson plans featured significantly more words (950), $t(27) = -2.40$, $p = 0.02$, and a significantly higher percentage usage of verbs (1.74%), $t(27) = 2.88$, $p = 0.008$. Post lesson plans used a significantly lower percentage of words related to social processes (1.44%) $t(27) = 3.20$, $p = 0.004$. Postlesson plans featured a significantly higher percentage of words related to affective processes (.89%), $t(27) = -2.86$, $p = 0.008$, positive emotion (1.22%), $t(27) = -5.09$, $p < 0.001$, cognitive processes (1.86%), $t(27) = -2.42$, $p = 0.02$, and achievement (1.01%), $t(27) = -2.91$, $p = 0.007$. These results suggest that participants' word choice in writing lesson differed from the prelesson plan to the postlesson plan.

Word frequencies were calculated for the prelesson ($n = 35$) and postlesson plans ($n = 41$) with the KH Coder text analysis software. Table 21 lists the most common nouns, verbs, and technology-related words found in each lesson plan group. Collocation statistics were calculated with KH Coder for the most common noun, verb, and technology-related words in the pre- and postlesson plans and are displayed in Tables 22 through 26. The collocation table show that *student* in the prelesson plan is collocated with words that describe what the student will do, be asked to do, or will be able to do. In the postlesson plans, *student* is situated among similar words but is also collocated with *allow* and *technology* that act as enablers for student actions. *Use* is the most common verb in both the pre- and postlesson plans. In both sets of lesson plans, *use* is collocated among words that suggest that students are using tools or processes to accomplish tasks. This context also suggests a focus on tools and processes rather than on the tasks to be accomplished. The pre- and postlesson plans share the three most common technology-related words of *video*, *computer* and *technology*; although in a slightly different order. In both lesson plan groups, *video* is collocated with words that suggest that students are making, watching, and posting videos. *Computer* is collocated with words that suggest that accessing computers in labs to complete work. *Technology* is collocated with words that suggest that students use technology and that technology is integrated into lessons and connected to standards.

Table 21

Pre- and Postlesson Plan Noun, Verb, and Technology Word Frequencies

Prelesson Plans						Postlesson Plans					
Noun	*n*	Verb	*n*	Technology	*n*	Noun	*n*	Verb	*n*	Technology	*n*
student	621	use	232	video	37	student	2224	use	711	technology	335
class	117	write	140	computer	28	lesson	591	create	306	computer	125
lesson	113	work	79	technology	24	technology	335	make	260	video	122
question	110	create	77	Google	16	class	307	learn	227	website	99
group	109	make	73	software	14	activity	296	work	199	blog	76
word	100	read	73	website	12	teacher	267	write	188	Google	68
teacher	95	learn	72	blog	9	information	240	need	164	glog	57
fraction	80	ask	70	SmartBoard	7	group	213	complete	148	PowerPoint	51
objective	67	explain	64	Graphic	6	project	204	include	140	internet	48
activity	66	explore	62	Internet	6	time	192	think	140	screencast	48
information	64	complete	59	Quest	6	assignment	171	allow	139	Edmodo	39
problem	59	follow	46	Web	6	question	171	follow	119	software	35
child	57	discuss	45	internet	5	work	143	explore	117	web	33
number	56	need	43	Edmodo	5	way	135	choose	100	Tumblr	31
point	52	check	39	PowerPoint	5	example	128	know	100	Wordle	27
time	50	share	37	YouTube	4	topic	126	provide	99	Internet	26
cloud	49	include	36			computer	125	help	98	Prezi	24
portion	48	help	32			fraction	122	teach	96	Blog	19
picture	47	identify	32			video	122	require	95	Microsoft	19
concept	46	look	32			grade	118	develop	93	Webquest	15

Table 22

Collocation Table for Student

	Prelesson Plan				Postlesson Plan		
Word	Total	Left*	Right*	Word	Total	Left*	Right*
write	43	8	35	use	178	41	137
work	36	1	35	lesson	131	107	24
ask	35	22	13	able	107	4	103
able	34	0	34	student	94	48	46
teacher	34	15	19	work	91	26	65
check	33	23	10	create	86	21	65
explore	33	15	18	teacher	86	43	43
objective	30	30	0	activity	85	64	21

Note. *Appears to the left or right of the key word within five words

Table 23

Collocation Table for Use

	Prelesson Plan				Postlesson Plan		
Word	Total	Left*	Right*	Word	Total	Left*	Right*
student	25	23	2	student	185	139	46
fraction	21	13	8	technology	102	24	78
strategy	19	9	10	tool	44	9	35
word	19	3	16	lesson	42	29	13
follow	17	1	16	spreadsheet	39	12	27
model	17	0	17	create	34	18	16
question	17	0	17	information	33	12	21
rock	16	12	4	fraction	28	17	11

Note. *Appears to the left or right of the key word within five words

Table 24

Collocation Table for Video

	Prelesson Plan				Postlesson Plan		
Word	Total	Left*	Right*	Word	Total	Left*	Right*
student	6	3	3	student	32	17	15
make	5	3	2	make	14	9	5
watch	5	5	0	watch	10	8	2
YouTube	4	1	3	BrainPOP	8	8	0
create	3	3	0	activity	7	5	2
need	3	2	1	need	7	4	3
show	3	2	1	use	7	3	4
watch	3	3	0	post	6	6	0

Note. *Appears to the left or right of the key word within five words

Table 25

Collocation Table for Computer

	Prelesson Plan				Postlesson Plan		
Word	Total	Left*	Right*	Word	Total	Left*	Right*
use	6	5	1	lab	44	1	43
day	5	5	0	student	28	20	8
lab	5	0	5	use	24	20	4
group	4	3	1	time	10	8	2
access	3	1	2	work	9	5	4
cold	3	0	3	station	6	1	5
information	3	0	3	access	5	3	2
materials	3	2	1	classroom	5	4	1

Note. *Appears to the left or right of the key word within five words

Table 26

Collocation Table for Technology

	Prelesson Plan				Postlesson Plan		
Word	Total	Left*	Right*	Word	Total	Left*	Right*
usage	5	0	5	student	85	38	47
use	5	4	1	use	75	56	19
concept	4	1	3	lesson	39	12	27
lesson	4	2	2	standard	32	6	26
plan	4	2	2	use	27	21	6
strand	4	2	2	integrate	25	23	2
create	3	2	1	classroom	24	4	20
implement	3	3	0	lesson	24	3	21

Note. *Appears to the left or right of the key word within five words

Co-occurrence networks were created with KH Coder for the pre- and postlesson plan groups as seen in Figures 2 and 3. The unit of analysis for each group of lesson plans was the paragraph, or more specifically, the networks display co-occurrences of words within paragraphs. The sizes of nodes in the network were determined by the frequency of the term in the lesson plan group and line thicknesses were determined by the Jaccard similarity coefficient. The Jaccard coefficient determines the similarity and diversity among words (Romesburg, 1984). The communities were assigned different colors and were determined by the fast greedy modularity algorithm (Clauset, Newman, & Moore, 2004). The network for the prelesson plans features six communities with more than three nodes. The overall prelesson plan network suggests the lesson plans in this group were focused on student activities and processes. Within the purple community, the most frequent word, *student*, has only two strong connections. Furthermore, the purple community describes writing that students share with partners. Similarly, the red community describes fractions and the development of strategies for use with fractions.

The orange community describes a reading and story boarding activity. The green community is focused on student and teacher processes, while the teal community starts with class processes that lead to a video activity.

The network for the postlesson plans features five communities with three or more nodes. The network is dominated by the large teal community that is focused on the relationships between students and their learning activities, teachers, and classroom. The yellow community describes a learning experience with Tumblr. The purple group describes an activity on fractions. The blue group is more focused on the instructional approach than a specific activity. The green group describes the structure of a lesson plan template. Overall, the postlesson plan network is focused less on activities and more on students and student learning.

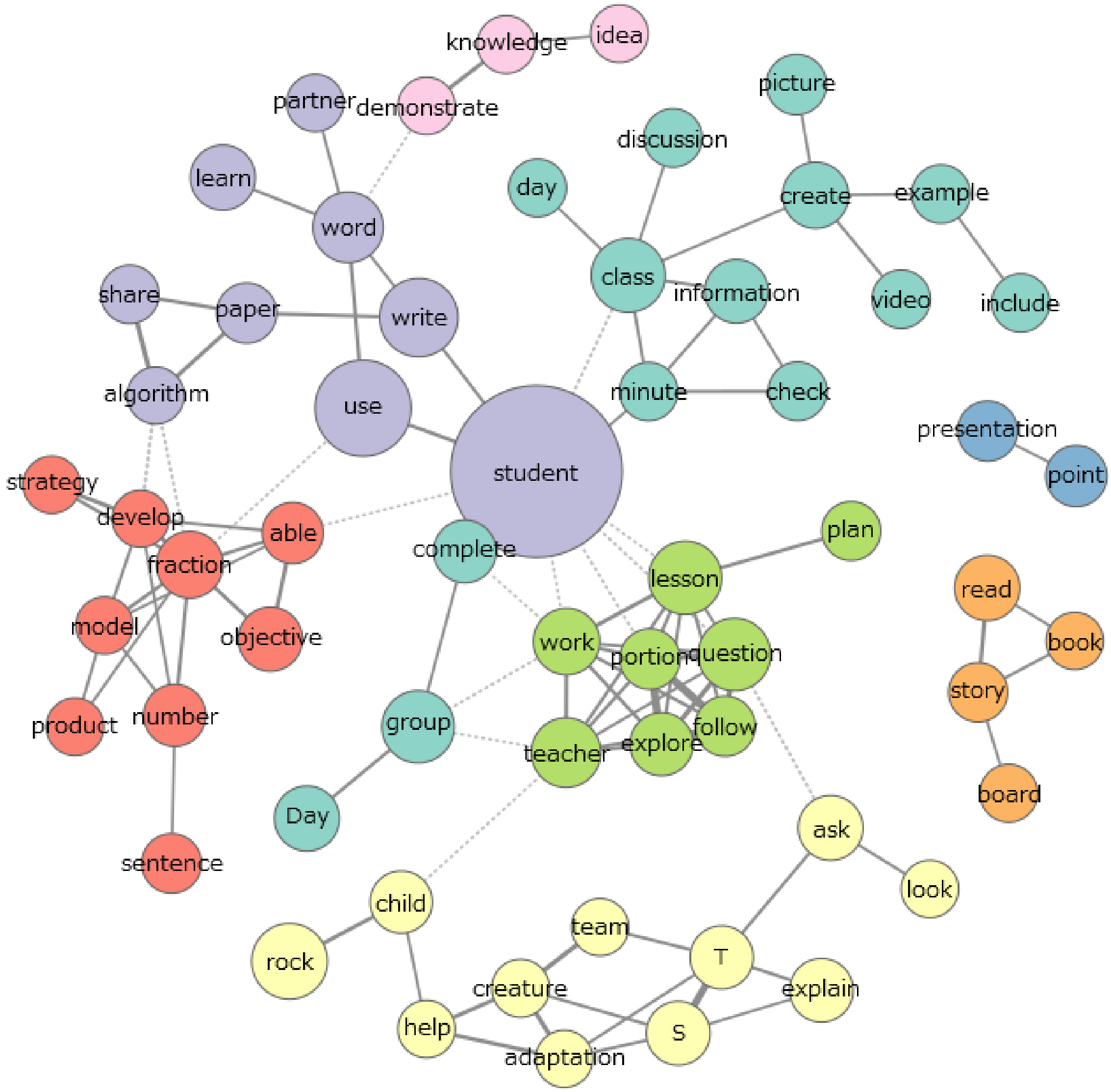

Figure 2. Co-occurrence network of the prelesson plan corpus.

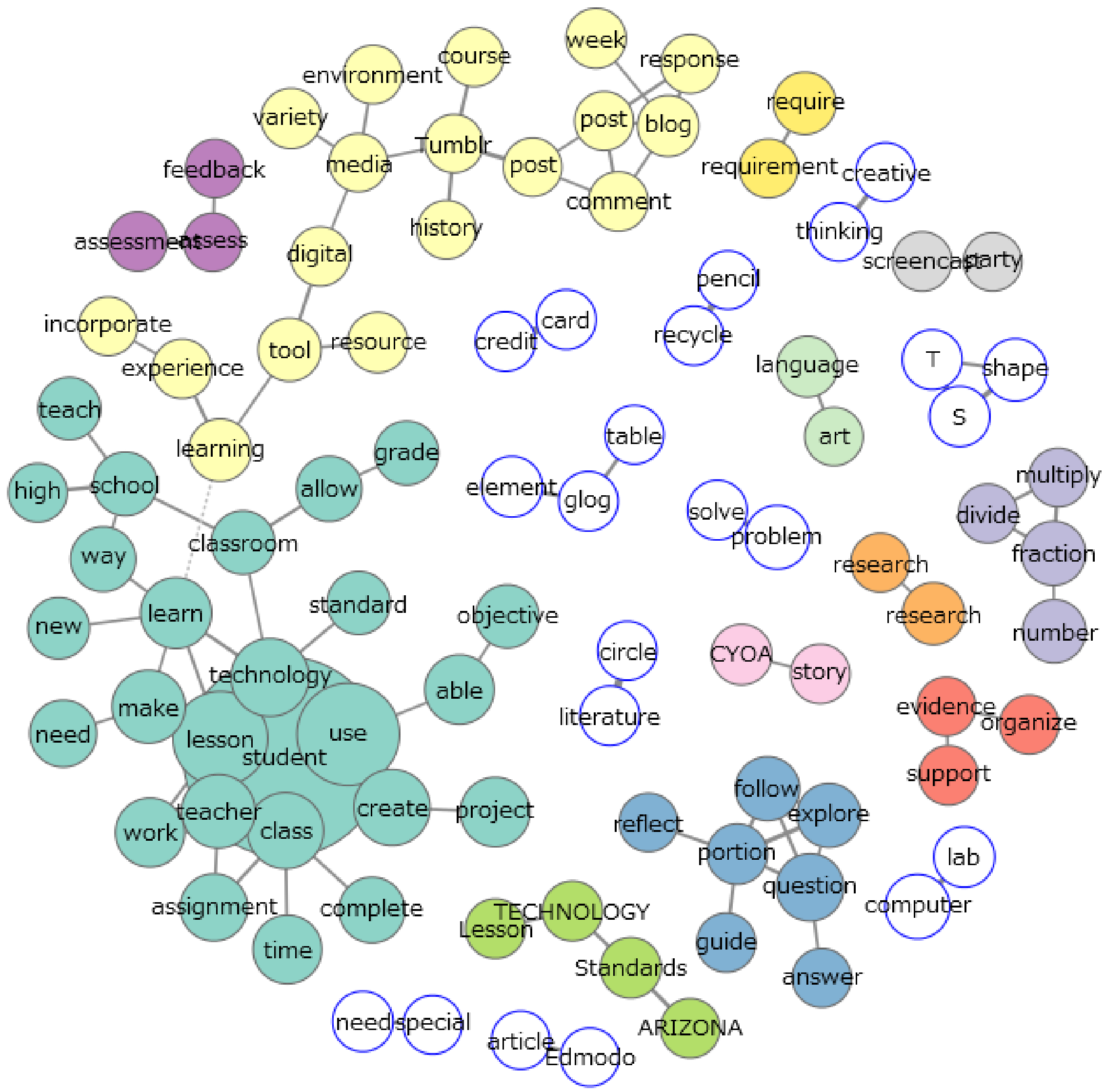

Figure 3. Co-occurrence network of the postlesson plan corpus.

TPACK Differences by Participant Characteristics

The analyses in this section were conducted to answer the question: How do students with higher levels of TPACK differ from those with lower levels of TPACK?

Treatment group survey. Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores by gender on the pre- and postsurvey. The independent variable, gender, included the two levels of male and female. The dependent variables were the seven TPACK constructs. The presurvey *F*-test was significant for PK, $F(1, 25.42) = 11.07$, $p = 0.003$; TK, $F(1, 13.26) = 5.16$, $p = 0.04$; CK, $F(1, 18.91) = 5.53$, $p = 0.03$; and TPK, $F(1, 27.46) = 5.03$, $p = 0.03$. Females ($n = 45$) scored significantly higher than males ($n = 12$) on PK (3.49 versus 2.89) and CK (3.48 versus 2.97), while males scored significantly higher than females on TK (3.42 versus 2.61) and TPK (2.98 versus 2.56). No postsurvey scores were significantly different between males and females. These results suggest preexisting differences between the genders may be eliminated following participation in an educational technology course. See Table 27 for the remainder of the Welch *F*-test statistics.

Table 27

Gender Differences in Pre- and Post-survey TPACK Constructs

Construct	Welch's *F*	*df*	*p*
Pre-PK	11.065	25.420	0.003
Pre-TK	5.115	13.259	0.041
Pre-CK	5.533	18.913	0.030
Pre-PCK	1.535	17.646	0.232
Pre-TCK	3.432	31.269	0.073
Pre-TPK	5.030	27.456	0.033
Pre-TPACK	0.212	24.679	0.649
Post-PK	0.006	10.405	0.942
Post-TK	3.331	7.175	0.110
Post-CK	0.000	14.814	0.992
Post-PCK	0.022	17.996	0.883
Post-TCK	2.488	10.003	0.146
Post-TPK	0.363	9.290	0.561
Post-TPACK	1.246	14.144	0.283

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores by age group on the pre- and postsurvey. The independent variable, age, included the four levels: 21 to 29 ($n = 33$), 30-39 ($n = 13$), 40 to 49 ($n = 5$), and 50 to 59 ($n = 6$). The dependent variables were the seven TPACK constructs. Both the pre- and postsurvey showed significant differences in TK, $F(3, 13.26) = 5.40$, $p = 0.01$ and $F(3, 8.07) = 12.05$, respectively. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified differences between the presurvey mean scores of the 21 to 29 age group (2.94) and the 50 to 59 age group (2.07) and the postsurvey mean scores of the same groups with 3.09 and 1.89, respectively. These results suggest that younger participants report higher technological ability than older participants.

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores among respondents' self-reported knowledge pedagogy on the postsurvey ($n = 39$). The independent variable—knowledge of pedagogy—included four levels: beginning ($n = 4$), intermediate ($n = 19$), advanced ($n = 16$) and expert ($n = 0$). The dependent variables were the seven TPACK constructs. The tests were significant for PK, $F(2, 8.20) = 8.00$, $p = 0.01$; CK, $F(2, 8.15) = 10.61$, $p = 0.005$; and PCK, $F(2, 7.81) = 9.14$, $p = 0.009$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores among beginning, intermediate, and advanced groups on CK. The test also identified significant differences in the mean scores between beginning and advanced groups on PK and PCK. These results suggest that participants with intermediate or advanced knowledge of pedagogy report higher ability than beginners on PK, CK, and PCK. See Table 28 for the significant differences in mean scores.

Table 28

Mean Score Differences Among Knowledge of Pedagogy Groups on TPACK Construct Scores

Construct	Group 1	Group 2	Mean Difference
Post-PK	Beginning	Intermediate	-1.44
		Advanced	-1.58*
	Intermediate	Beginning	1.44
		Advanced	-0.14
Post-CK	Beginning	Intermediate	-1.86*
		Advanced	-2.10*
	Intermediate	Beginning	1.86*
		Advanced	-0.24
Post-TK	Beginning	Intermediate	0.01
		Advanced	-0.40
	Intermediate	Beginning	-0.01
		Advanced	-0.40
Post-PCK	Beginning	Intermediate	-1.41
		Advanced	-1.63*
	Intermediate	Beginning	1.41

Note. $^*p < 0.05$

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores among respondents' self-reported knowledge content on the postsurvey ($n = 39$). The independent variable of knowledge of content included four levels: beginning ($n = 5$), intermediate ($n = 9$), advanced ($n = 23$) and expert ($n = 2$). The dependent variables were the seven TPACK constructs. The tests were not significant.

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores among respondents' self-reported knowledge level of educational technology on the postsurvey (*n* = 39). The knowledge of educational technology independent variable included four levels: beginning (*n* = 7), intermediate (*n* = 21), advanced (*n* = 11) and expert (*n* = 0). The dependent variables were the seven TPACK constructs. The tests were significant for six of the seven constructs: TK, $F(2, 17.59) = 15.12$, $p < 0.001$; CK, $F(2, 13.19) = 4.35$, $p = 0.04$; TCK, $F(2, 13.87) = 8.05$, $p = 0.005$; TPK, $F(2, 14.80) = 13.63$, $p < 0.001$; and TPACK, $F(2, 14.95) = 8.77$, $p = 0.003$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores among beginning, intermediate, and advanced on TK, TCK, and TPACK. The test also identified significant differences in the mean scores between beginning and intermediate on CK and beginning and advanced on TPACK. These results suggest that participants with intermediate or advanced knowledge of educational technology report higher ability than beginners CK, TK, TCK, and TPACK. See Table 29 for the significant differences in mean scores.

Table 29

Mean Score Differences Among Knowledge of Educational Technology Groups on TPACK Construct Scores

Construct	Group 1	Group 2	Mean Difference
Post-PK	Beginning	Intermediate	-0.87
		Advanced	-0.73
	Intermediate	Beginning	0.87
		Advanced	0.14
Post-CK	Beginning	Intermediate	-1.43*
		Advanced	-1.32
	Intermediate	Beginning	1.43*
		Advanced	0.11
Post-TK	Beginning	Intermediate	-1.17*
		Advanced	-1.68*
	Intermediate	Beginning	1.17*
		Advanced	-0.50
Post-PCK	Beginning	Intermediate	-0.93
		Advanced	-0.82
	Intermediate	Beginning	0.93
		Advanced	0.11
Post-TCK	Beginning	Intermediate	-1.24*
		Advanced	-1.34*
	Intermediate	Beginning	1.24*
		Advanced	-0.10
Post-TPK	Beginning	Intermediate	-1.35*
		Advanced	-1.32*
	Intermediate	Beginning	1.35*
		Advanced	0.03
Post-TPACK	Beginning	Intermediate	-0.94
		Advanced	-1.31*
	Intermediate	Beginning	0.94
		Advanced	-0.37

Note. * The mean difference is significant at the 0.05 level.

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct difference (pre- minus post) scores among respondents' self-reported knowledge of pedagogy ($n = 39$). The knowledge of pedagogy independent variable, included four levels: beginning ($n = 4$), intermediate ($n = 19$), advanced ($n = 16$), and expert (n = 0). The dependent variables were the seven TPACK construct differences scores. The tests were significant for CK, $F(2, 9.91) = 7.21$, $p = 0.01$, and PCK, $F(2, 12.30) = 7.94$, $p = 0.006$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores between beginning and advanced groups on CK (-1.23) and PCK (-1.17). These results suggest that participants with advanced knowledge of pedagogy have higher gains over time in CK and PCK than pedagogy beginners.

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct difference (pre minus post) scores among respondents' self-reported knowledge of content on the postsurvey (n = 39). The independent variable of knowledge of content included four levels: beginning (n = 5), intermediate (n = 9), advanced (n = 23), and expert (n = 2). The dependent variables were the seven TPACK construct difference scores. The test was significant for PCK, $F(3, 5.29) = 5.50$, $p = 0.05$. Follow-up tests were conducted to evaluate pariwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores between the beginning and advanced group on PCK (-0.92). These results suggest that participants with advanced knowledge of content have higher gains over time in PCK than content beginners.

Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct difference (pre minus post) scores among respondents' self-reported knowledge level of educational technology on the postsurvey (n = 39). The knowledge of educational technology independent variable included four levels: beginning (n = 7), intermediate (n = 21), advanced (n = 11), and expert (n = 0). The dependent variables were the seven

TPACK construct difference scores. The tests were significant for five of the seven constructs: PK, $F(2, 20.50) = 4.54$, $p = 0.02$; CK, $F(2, 18.58) = 4.86$, $p = 0.02$; TCK, $F(2, 17.58) = 4.56$, $p = 0.03$; TPK, $F(2, 19.23) = 5.45$, $p < 0.01$; and TPACK, $F(2, 18.68) = 3.94$, $p = 0.04$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores between beginning and intermediate groups on PK (-0.71), CK (-0.87), TCK (-0.83), and TPK (-0.79). These results suggest that participants with intermediate knowledge of educational technology have higher gains over time in PK, CK, TCK, and TPK than educational technology beginners.

Linear regression analyses were conducted to evaluate how years of teaching experience predicted the seven TPACK construct scores on both the pre- and postsurvey. The regression was significant for PK scores on the postsurvey, F(1, 50) = 5.20, $p = 0.03$, $R^2 = 0.09$. The remaining regression analyses were not significant. These results suggest that participants with more years of teaching tend to have higher reported ability in PK, but not in any of the other TPACK constructs.

Multiple regression analyses were conducted to evaluate how well the number of credit hours related to pedagogy, content, and technology predicted the seven TPACK constructs on the pre- and postsurvey. The predictors were the number of pedagogy-related credit hours completed, the number of content-related credit hours completed, and the number of technology-related content hours completed. The linear combination of completed credit hours was significantly related to the PK score on the presurvey, F(3, 29) = 4.26, $p = 0.01$. The R^2 coefficient was 0.31, which indicate that approximately 31% of the variance in the PK score on the presurvey can be accounted for by the linear combination of credit hours taken. Content credit hours, $t(31) = -2.32$, $p = 0.03$ and technology credit hours, $t(31) = 3.18$, $p = 0.003$, made significant contributions to the prediction equation while pedagogy credit hours did not, $t(31) = 1.33$, $p = 0.19$. Also of note is the unexpected negative correlation between content credit hours and PK score on the presurvey and the negative standardized Beta coefficient (-0.45) in the prediction equation. Table 30 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in content and technology report higher PK ability on the presurvey.

Table 30

Bivariate and Partial Correlations of the Predictors with PK Presurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.14	0.24
Content credit hours	-0.10	-0.40*
Technology credit hours	0.42**	0.51**

Note. * $p < 0.05$, ** $p < 0.01$

The linear combination of completed credit hours was not significantly related to the CK score on the presurvey, $F(3,29) = 2.11$, $p = 0.12$. However, technology credit hours made a significant contribution to the prediction equation, $t(31) = 2.07$, $p = 0.05$, and was significantly correlated, $r(31) = .30$, $p = 0.05$, with CK scores on the presurvey. These results suggest that participants who took more credit hours in technology report higher PK scores on the presurvey.

The linear combination of completed credit hours was significantly related to the PCK score on the presurvey, $F(3, 29) = 5.53$, $p = 0.004$. The R^2 coefficient was 0.36, which indicates that approximately 36% of the variance in the PCK score on the presurvey can be accounted for by the linear combination of the credit hours taken. Pedagogy credit hours, $t(31) = 3.17$, $p = 0.004$, and technology credit hours, $t(31) = 2.22$, $p = 0.04$, made significant contributions to the prediction equation while content credit hours did not, $t(31) = -1.65$, $p = 0.11$. Table 31 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in pedagogy and technology report higher PCK ability on the presurvey.

Table 31

Bivariate and Partial Correlations of the Predictors with PCK Presurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.49**	0.51**
Content credit hours	0.14	-0.29
Technology credit hours	0.38*	0.38*

Note. * $p < 0.05$, ** $p < 0.01$

The linear combination of completed credit hours was significantly related to the TPACK score on the presurvey, $F(3,29) = 4.70$, $p = 0.009$. The R^2 coefficient was 0.33, which indicates that approximately 33% of the variance in the TPACK score on the presurvey can be accounted for by the linear combination of the credit hours taken. Pedagogy credit hours, $t(31) = 3.14$, $p = 0.004$, and content credit hours, $t(31) = -2.72$, $p = 0.01$, made significant contributions to the prediction equation while technology credit hours did not, $t(31) = 1.80$, $p = 0.08$. Table 32 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in pedagogy and content reported higher TPACK ability on the presurvey.

Table 32

Bivariate and Partial Correlations of the Predictors with TPACK Presurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.37*	0.50**
Content credit hours	-0.10	-0.45*
Technology credit hours	0.23	0.32

Note. * $p < 0.05$, ** $p < 0.01$

The linear combination of completed credit hours was significantly related to the PK score on the postsurvey, F(3, 29) = 3.93, $p = 0.02$. The R^2 coefficient was 0.28, which indicates that approximately 28% of the variance in the PK score on the postsurvey can be accounted for by the linear combination of credit hours taken. Technology credit hours, $t(31) = 3.32$, $p = 0.002$, made a significant contribution to the prediction equation while pedagogy credit hours, $t(31) = 0.55$, $p = 0.59$, and content credit hours, $t(31) = -1.72$, $p = 0.10$ did not. Table 33 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in technology reported higher PK ability on the postsurvey.

Table 33

Bivariate and Partial Correlations of the Predictors with PK Postsurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.09	0.10
Content credit hours	-0.05	-0.30
Technology credit hours	0.46**	0.52**

Note. * $p < .05$, ** $p < .01$

The linear combination of completed credit hours was significantly related to the CK score on the postsurvey, $F(3, 29) = 3.18$, $p = 0.04$. The R^2 coefficient was 0.24, which indicated that approximately 24% of the variance in the CK score on the postsurvey can be accounted for by the linear combination of credit hours taken. Technology credit hours, $t(31) = 2.79$, $p = 0.009$, made a significant contribution to the prediction equation while pedagogy credit hours, $t(31) = 0.99$, $p = 0.33$, and content credit hours, $t(31) = -1.87$ did not. Table 34 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in technology reported higher CK ability on the postsurvey.

Table 34

Bivariate and Partial Correlations of the Predictors with CK Postsurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.13	0.18
Content credit hours	-0.07	-0.32
Technology credit hours	0.39*	0.45**

Note. * $p < 0.05$, ** $p < 0.01$

The linear combination of completed credit hours was not significantly related to the PCK score on the postsurvey, $F(3,29) = 2.30$, $p = 0.10$. However, technology credit hours made a significant contribution to the prediction equation, $t(31) = 2.19$, $p = 0.04$, and was significantly correlated, $r(31) = .33$, $p = 0.03$, with PCK scores on the postsurvey. These results suggest that participants who took more credit hours in technology reported higher PCK ability on the postsurvey.

The linear combination of completed credit hours was significantly related to the TPACK score on the postsurvey, $F(3,29) = 2.94$, $p = 0.05$. The R^2 coefficient was 0.23, which indicates that approximately 23% of the variance in the TPACK score on the postsurvey can be accounted for by the linear combination of the credit hours taken. Content credit hours, $t(31) = -2.63$, $p = 0.01$, and technology credit hours, $t(31) = 2.04$, $p = 0.05$, made significant contributions to the prediction equation while pedagogy credit hours did not, $t(31) = 1.35$, $p = 0.19$. Table 35 presents indices to indicate the relative strength of the individual predictors. These results suggest that participants who took more credit hours in content and technology reported higher TPACK ability on the postsurvey.

Table 35

Bivariate and Partial Correlations of the Predictors with TPACK Postsurvey Score

Predictors	Correlation	Partial Correlation
Pedagogy credit hours	0.09	0.24
Content credit hours	-0.24	-.043*
Technology credit hours	0.22	0.35*

Note. * $p < 0.05$, ** $p < 0.01$

Multiple regression analyses were conducted to evaluate how well the number of hours per day spent using technology predicted the seven TPACK constructs on the presurvey. The predictors were the number of hours per day spent using technology for professional purposes and the number of hours per day spent using technology for personal purposes. The regression equation with the presurvey PK score criterion variable was significant, $F(2, 33) = 4.38$, $p = 0.02$. The R^2 coefficient was 0.21, which indicates that approximately 21% of the variance in the PK score on the presurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(33) = 2.96$, $p = 0.006$, made a significant contribution to the prediction equation while personal hours did not, $t(33) = -.75$, $p = 0.46$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher PK ability on the presurvey.

The regression equation with the presurvey CK score criterion variable was significant, $F(2, 33) = 4.00$, $p = 0.03$. The R^2 coefficient was 0.20, which indicates that approximately 20% of the variance in the CK score on the presurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(33) = 2.79$, $p = 0.009$, made a significant contribution to the prediction equation while personal hours did not, $t(31) = -1.17$, $p = 0.25$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher CK ability on the presurvey.

The regression equation with the presurvey PCK score criterion variable was significant, $F(2, 33) = 1.52$, $p = 0.02$. The R^2 coefficient was 0.21, which indicates that approximately 21% of the variance in the PCK score on the presurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(33) = 2.77$, $p = 0.009$, made a significant contribution to the prediction equation while personal hours did not, $t(33) = -1.78$, $p = 0.09$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher PCK ability on the presurvey.

The regression equation with the presurvey TCK score criterion variable was significant, $F(2, 33) = 4.11$, $p = 0.03$. The R^2 coefficient was 0.20, which indicates that approximately 20% of the variance in the TCK score on the presurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(33) = 2.72$, $p = 0.01$, made a significant contribution to the prediction equation while personal hours did not, $t(33) = .22$, $p = 0.83$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TCK ability on the presurvey.

The linear combination of hours spent using technology personally and professionally was not significantly related to the TPK score on the presurvey, $F(2, 33) = 2.90$, $p = 0.07$. However, professional hours spent made a significant contribution to the prediction equation, $t(31) = 2.33$, $p = 0.03$, and was significantly correlated, $r(33) = .37$, $p = 0.01$, with TPK scores on the presurvey. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TPK ability on the pre-survey.

The linear combination of hours spent using technology personally and professionally was not significantly related to the TPACK score on the presurvey, $F(2, 33) = 2.70$, $p = 0.08$. However, professional hours spent made a significant contribution to the prediction equation, $t(33) = 2.29$, $p = 0.03$, and was significantly correlated, $r(33) = .37$, $p = 0.01$, with TPACK scores on the postsurvey. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TPACK ability on the presurvey.

The linear combination of hours spent using technology personally and professionally was not significantly related to the PK score on the postsurvey, $F(2, 34) = 2.25$, $p = 0.12$. However, professional hours spent made a significant contribution to the prediction equation, $t(34) = 2.11$, $p = 0.04$, and was significantly correlated, $r(34) = 0.34$, $p = 0.02$, with TPACK scores on the postsurvey. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher PK ability on the postsurvey.

The linear combination of hours spent using technology personally and professionally was not significantly related to the TK score on the postsurvey, $F(2, 34) = 2.73$, $p = 0.08$. Neither predictor made a significant contribution to the prediction equation, however, both professional time spent, $r(34) = .31$, $p = 0.03$, and personal time spent, $r(34) = .27$, $p = 0.05$ were significantly correlated with TK scores on the postsurvey. Although the linear combination of the two predictors did not significantly predict TK scores, these results suggest that participants who spent more hours using technology professionally or personally tended to report higher TK ability on the postsurvey.

The regression equation with the postsurvey CK score criterion variable was significant, $F(2, 34) = 4.64$, $p = 0.02$. The R^2 coefficient was 0.22, which indicates that approximately 22% of the variance in the CK score on the postsurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(34) = 3.02$, $p = 0.005$, made a significant contribution to the prediction equation while personal hours did not, $t(34) = -.25$, $p = 0.80$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher CK ability on the postsurvey.

The linear combination of hours spent using technology personally and professionally was not significantly related to the PCK score on the postsurvey, $F(2, 34) = 2.42$, $p = 0.10$. However, professional hours spent made a significant contribution to the prediction equation, $t(34) = 2.14$, $p = 0.04$, and was significantly correlated, $r(34) = 0.35$, $p = 0.02$, with PCK scores on the postsurvey. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher PCK ability on the postsurvey.

The regression equation with the postsurvey TCK score criterion variable was significant, $F(2, 34) = 6.81$, $p = 0.003$. The R^2 coefficient was 0.29, which indicates that approximately 29% of the variance in the TCK score on the postsurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(34) = 3.37$, $p = 0.002$, made a significant contribution to the prediction equation while personal hours did not, $t(34) = 0.73$, $p = 0.47$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TCK ability on the postsurvey.

The regression equation with the postsurvey TPK score criterion variable was significant, $F(2, 34) = 4.56$, $p = 0.02$. The R^2 coefficient was 0.21, which indicates that approximately 21% of the variance in the TPK score on the postsurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(34) = 2.77$, $p = 0.009$, made a significant contribution to the prediction equation while personal hours did not, $t(34) = 0.58$, $p = 0.57$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TPK ability on the postsurvey.

The regression equation with the postsurvey TPACK score criterion variable was significant, $F(2, 34) = 4.25$, $p = 0.02$. The R^2 coefficient was 0.20, which indicates that approximately 20% of the variance in the TPACK score on the postsurvey can be accounted for by the linear combination of hours per day spent using technology. Professional hours spent, $t(34) = 2.80$, $p = 0.008$, made a significant contribution to the prediction equation while personal hours did not, $t(34) = 0.18$, $p = 0.86$. These results suggest that participants who spent more hours per day using technology for professional purposes reported higher TPACK ability on the postsurvey.

Lesson plan rubric scores. Welch ANOVA *F*-tests were conducted to evaluate differences in TPACK construct scores by gender on the pre- and postcourse rubric. The independent variable *gender* included the two levels of male and female. The dependent variables were the seven TPACK constructs. The precourse *F*-test was significant for TK, $F(1, 30.26) = 10.54$, $p = 0.003$; TPK, $F(1, 27.48) = 7.00$, $p = 0.01$; TCK, $F(1, 22.00) = 12.14$, $p = 0.002$; and TPACK, $F(1, 19.63) = 11.05$, $p = 0.003$. Females ($n = 26$) scored significantly higher than males ($n = 7$) on TK (2.17 versus 1.36), TPK (2.11 versus 1.41), TCK (2.74 versus. 1.61), and TPACK (2.63 versus 1.61). No postcourse rubric scores were significantly different between males and females. These results suggest preexisting differences between the genders may be eliminated following participation in an educational technology course. See Table 36 for the remainder of the Welch *F*-test statistics.

Table 36

Gender Differences in Pre- and Postlesson Plan Rubric Construct Scores

Construct	Welch's *F*	*df*1, *df*2	*p*
Pre-PK	1.82	1, 8.82	0.21
Pre-CK	1.20	1, 9.16	0.30
Pre-TK	10.53	1, 30.26	0.00
Pre-PCK	0.25	1, 7.90	0.63
Pre-TCK	12.14	1, 22.00	0.00
Pre-TPK	6.99	1, 27.48	0.01
Pre-TPACK	11.05	1, 19.63	0.00
Post-PK	3.45	1, 11.19	0.09
Post-TK	0.06	1, 13.53	0.81
Post-CK	0.40	1, 7.81	0.54
Post-PCK	1.28	1, 8.00	0.29
Post-TCK	0.45	1, 7.76	0.52
Post-TPK	0.88	1, 12.23	0.37
Post-TPACK	0.01	1, 8.28	0.94

Welch ANOVA *F*-tests were conducted to evaluate differences in pre- and postcourse rubric construct scores among respondents' self-reported knowledge of pedagogy ($n = 34$). The independent variable of knowledge of pedagogy included four levels: beginning ($n = 4$), intermediate ($n = 15$), advanced ($n = 15$), and expert ($n = 0$). The dependent variables were the seven TPACK constructs. None of the tests were significant for the precourse rubric constructs. The test was significant for the postcourse rubric TK score, $F(2, 17.12) = 8.43$, $p = 0.003$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean TK scores between the beginning and advanced groups (-1.12). These results suggest that participants with advanced knowledge of pedagogy demonstrate higher TK proficiency than beginners.

Welch ANOVA *F*-tests were conducted to evaluate differences in pre- and postcourse rubric construct scores among respondents' self-reported knowledge of content ($n = 34$) and educational technology ($n = 34$). The independent variable of knowledge of content included four levels: beginning ($n = 4$), intermediate ($n = 9$), advanced ($n = 19$), and expert ($n = 2$). The independent variable of knowledge of educational technology included four levels: beginning ($n = 7$), intermediate ($n = 17$), advanced ($n = 10$), and expert ($n = 0$). The dependent variables were the seven TPACK constructs. None of the tests were significant for knowledge of content. For knowledge of educational technology, the tests were significant for postcourse rubric scores on PK, $F(16.63) = 7.65$, $p = 0.004$, and CK, $F(2, 15.09) = 4.16$, $p = 0.04$. Follow-up tests were conducted to evaluate pairwise differences among the mean scores using Dunnett's *C* test. The test identified significant differences in the mean scores between the beginning and intermediate groups for PK (-0.92) and CK (-0.91). These results suggest that participants with intermediate knowledge of educational technology demonstrate higher PK and CK proficiency than beginners.

Linear regression analyses were conducted to evaluate how years of teaching experience predicted the seven TPACK construct scores on both the pre-and postcourse rubric scores. The regression was significant for TK scores on the precourse rubric, $F(1, 29) = 4.65$, $p = 0.04$, $R^2 = 0.14$. The remaining regression analyses were not significant. These results suggest that participants with more teaching experience demonstrated higher TK proficiency on the precourse lesson plan than those with less teaching experience.

In addition, multiple regression analyses were conducted to evaluate how well the number of pedagogy, content, and technology-related credit hours predicted the seven TPACK constructs on the pre- and postcourse rubric scores. The predictors were the number of pedagogy-related credit hours completed, the number of content-related credit hours completed, and the number of technology-related content hours completed. The linear combination of completed credit hours was not significantly related to any of the TPACK construct scores. These results suggest the number of credit hours taken did not affect the demonstration of TPACK construct proficiency in lesson plans.

Multiple regression analyses were conducted to evaluate how well the number of hours per day spent using technology predicted the seven TPACK constructs from the pre- and postcourse rubric. The predictors were the number of hours per day spent using technology for professional purposes and the number of hours per day spent using technology for personal purposes. The regression equation with the precourse rubric CK score criterion variable was significant, $F(2, 25) = 4.78$, $p = 0.02$. The R^2 coefficient was 0.28, which indicates that approximately 28% of the variance in the CK score on the precourse rubric can be accounted for by the linear combination of hours per day spent using technology. Personal hours spent, $t(25) = 2.76$, $p = 0.01$ made a significant contribution to the prediction equation. These results suggest that participants who spent more hours per day using technology for personal purposes demonstrated higher CK proficiency on the precourse lesson plan.

Teaching and Learning Experiences

The analyses in this section were conducted to answer two questions: 1) How do students with higher levels of TPACK differ from those with lower levels of TPACK?

and 2) What teaching and learning experiences influenced students' knowledge of and practice in teaching?

Interview participants were purposefully selected based on their overall presurvey mean score, which ranged from 1.26 to 3.74. Participants were categorized into low (n = 3), middle (n = 5), and high (n = 3) scoring groups for analysis. Inductive data analysis was performed on each of the 11 interview transcripts by first employing open coding and then axial coding to develop codes, categories, and themes (Lewins & Silver, 2007). During the open coding phase, descriptive codes were developed based on the emerging information from the interview transcripts. During the axial coding phase, the descriptive codes were grouped into categories and themes based on the TPACK framework. The results from the three groups are organized by theme, which are defined by the core constructs in TPACK: pedagogy, content, and technology.

Low group. The low-scoring group included Christa, a substitute kindergarten through twelfth grade (K-12) teacher with 15 years of part-time teaching experience; Keanu, a communications lecturer at the undergraduate level with 10 years of teaching experience; and Tatiana, a substitute middle school teacher with one year of part-time teaching experience. Christa had the lowest mean presurvey score of any study participant with a 1.26. Keanu had a presurvey score of 2.71 and Tatiana had a presurvey score of 2.89.

Pedagogy. Christa and Tatiana described their typical lessons in broad strokes, which included warm-up activities, presenting notes, small group work, responding to student questions, and students completing homework in class. Keanu described the PowerPoint slides and video links that he posts in his Blackboard course site.

Furthermore, the group described their lesson planning influences that included internet resources, textbooks, and program goals and objectives. While Tatiana said that her mentor teacher during her student teaching experience had an influence on her lesson planning, Christa stated that full-time teachers were not willing to share ideas with her as a substitute.

Christa was not confident in her knowledge of effective teaching methods although she did suggest that student collaboration in small groups and project-based activities were effective. Keanu and Tatiana also said that project-based learning was an effective method when compared with passive learning methods. Tatiana thought that one-on-one instruction was the most effective method, whether the pairing is teacher-to-student or student-to-student. The group learned about effective teaching methods from their graduate courses, from the internet, and from their student teaching experience. The group found that these methods were effective by testing them out in the classroom, but only Keanu mentioned that the methods were effective as judged by student evaluations and assessment scores.

Content. The group was drawn to their respective content areas through their experiences in middle school or junior high school. Significant influences or resources in their content areas included online resources, teacher observations, professional development, and college content instructors.

Technology. Outside of teaching, the group said that they enjoyed using technology in personal and work contexts. They largely learned to use those technologies through individual practice or trial and error; however, they learned to use educational technologies through formal coursework. The group agreed that teaching with technology was a beneficial practice. In particular, synchronous communication technologies and technologies that students could access outside of class could enrich students' experience. They did have some practical concerns regarding a lack of access to technology and were skeptical of the value of educational games. Although they held these opinions, only Keanu had implemented technology in his teaching. He had taken advantage of presentation technologies including slides, video, and animations. Keanu's graduate level content work influenced his use of technology because it fit with the content of the course and the theories used in the course.

Middle group. The mid-scoring group included the following participants: Karina, a sixth grade math and science teacher with three years of experience; Erica, a seventh grade social studies teacher with six years of experience; Alana, a math tutor and substitute teacher for grades kindergarten through ninth with four and a half years experience as a tutor and two years of part-time teaching experience; Maya, a Title I math teacher for grades kindergarten through eighth with six years of experiences; and Sally, a current online teacher trainer and former history teacher for grades 10 and 11 with three years of experience. Karina had the lowest mean pre-survey score of the mid group with a 2.90. Erica had a pre-survey score of 2.93, Alana had a pre-survey score of 2.89, Maya had a pre-survey score of 3.23, and Sally had a pre-survey score of 3.24

Pedagogy. Typical lessons for Karina, Erica, and Maya featured warm-up activities or assessments, presentations or explorations, independent or small group work, partner questions or class discussion, and a summary activity or an essential question to close the lesson. Their lessons were influenced by school-adopted curriculum programs or curriculum programs learned through undergraduate and graduate coursework. As a substitute teacher, Alana described English students watching content-related videos and completing online vocabulary activities, while history students read and answered questions and math students complete math worksheets. Alana's lesson planning was influenced by her mentor teacher's use of the "I do, we do, you do" model. Sally worked with online teachers individually and did not have set lesson activities, although her actions in that context were influenced by her online graduate courses.

The group discussed a variety of effective teaching methods including structured discussion, partner questioning, small group instruction, and accessible online materials with direct access to an instructor. Aside from Sally, the group learned their effective methods through school professional development sessions and from their mentor teachers in their student teaching experiences. Sally learned her online skills through her graduate coursework. The group found that these methods were effective by testing them out in the classroom. Only Erica mentioned that the methods were effective as judged by individual student assessment scores and class mastery goals.

Content. Major influences on the groups' content knowledge included professional development, content-specific resources, mentor teachers and teacher colleagues, formal courses, and content-specific curriculum programs. The group was largely drawn to their content area through a long-standing personal interest in the subject. Only Karina came to her content area by accident when her school needed a math teacher.

Technology. Outside of teaching, the group said that they enjoyed using technology in personal and work contexts. They largely learned to use those technologies through individual practice or trial and error. Only Karina and Alana said that they learned to use technologies through professional development or formal coursework. While teaching with technology was seen by the group in a positive light, they stressed the importance of appropriate use. The group saw educational technology as a way to engage students and enable individualized instruction, but warned that technology should complement, not replace teaching. Erica said that education is too quick to follow technology trends despite a lack of evidence to prove effectiveness. In purist of a grant that provided a class a set of iPads, Erica's secondary research suggested iPads were not as effective as laptops due to the quality of applications (or apps) available on the device.

The group developed their opinions on teaching with technology through coursework, professional development, and experience. Maya said that educational technology was not a focus in her undergraduate teacher education program. She felt she was not implementing technology effectively until she completed a graduate course in educational technology. The group's initial integrations of technology involved the use of presentation technologies like PowerPoint and document cameras, as well as self-contained, content-specific practice software like Plato. The group also used technology to gain student attention and organize information. They were influenced to take teaching with technology further by professional development sessions, graduate coursework in educational technology, and observations of other teachers.

High group. The high-scoring group included the following participants: John, a current achievement advisor for kindergarten and first grade for one school year and former math and science teacher for grades 7 and 8 for six years; Malia, a world studies and government teacher for grades 10 and 12 with 4 years of experience; and Laura, a sixth grade online Earth science teacher with nine years of experience. John had the lowest mean pre-survey score of the high group with a 3.35. Malia had a pre-survey score of 3.40 and Laura had a pre-survey score of 3.73.

Pedagogy. A typical lesson for John and Malia included a warm-up activity, direct instruction or a demonstration, and independent work or an application activity. The two often integrated a SMART Board, PowerPoint slides, and a student response system into their lessons. As an online teacher, Laura conducted synchronous online sessions that complement offline textbook lessons. First she reviewed previous material, then previewed and discussed current material. She designed lessons to engage higher-order thinking skills with methods connected to work by Robert J. Marzano and Benjamin S. Bloom. John's lessons conform to the district mandated lesson structure, while Malia's lessons were influenced by teaching experience and observing other teachers and professors. Laura's lessons were influenced by the common core standards and structured around established teaching frameworks and strategies.

The group's most effective teaching methods included small-group discovery learning, modeling, and generating hypotheses. The group said that giving students responsibility for their learning and enabling students to be creative were also effective methods. The group learned their effective teaching methods through coursework, professional development, and teaching experience. John and Malia said that they found their methods to be effective because students were more engaged in learning. Laura chose her methods based on evidence of effectiveness from educational research studies.

Content. The group's content knowledge was most influenced by formal undergraduate and graduate coursework, workshops, and independent study. John said that collaborating with other math and science teachers during shared planning time was also an influence. The group members said they all had long-standing personal interest in their content areas.

Technology. Outside of teaching, the group said that they enjoyed using technology in personal and work contexts. They largely learned to use those technologies through individual practice or trial and error. All the members said that teachers should use technology to teach and should expose students to technology. John said that teachers should not have the choice to avoid teaching with technology because they were afraid to use it or were uncomfortable using it. He suggested that wary teachers start out completing administrative tasks to become more comfortable with technology. Malia and Laura said that, while beneficial, technology could be distracting and was not appropriate for all occasions. Malia witnessed students that were distracted from the learning objective because they were struggling with the technology. Laura had seen how digital representations could help students learn science concepts, but if the technology became a barrier she advised her students to use paper and pencil in appropriate situations.

The group's initial integrations of technology involved the use of early web pages as resources and presentation technologies like ActivBoard, ActivInspire, and PowerPoint. They decided to integrate those technologies because they saw the technology was effective with other teachers and made lectures more engaging. John said that his first attempts at technology integration were simplistic, but they became more advanced and interactive with practice. John and Malia said that their current technology practices were influenced by their graduate coursework. Additionally, Malia was guided by the belief that students need to learn to use technologies to be productive citizens.

Laura’s practice is influenced by colleagues, workshops, and through regular reading of educational technology sites like Edutopia and Mind/Shift.

Chapter 4

DISCUSSION

Discussion of the Main Purpose

The purpose of this study was to investigate the initial shape of Technological Pedagogical Content Knowledge (TPACK) in graduate teacher education students and the influence of an educational technology course on the malleability of students' TPACK as measured by perceived ability, artifacts of practice, and personal experience. Table 37, a joint display, presents findings from the quantitative and qualitative phases of this study so that they are easily compared. This chapter will explore these and other findings along with their implications, limitations, and related directions for future research.

Table 37

Quantitative and Qualitative Phase: Joint Display

Method	Data Set	PK	CK	TK	PCK	TPK	TCK	TPACK
Quantitative	Treatment group survey gains	0.25*	0.39**	0.38*	0.26*	0.68**	0.67**	0.45**
	Control group survey gains†	-0.05	-0.18	-0.16	0.16	0.28	0.14	0.16
	Rubric gains	-0.24	-0.31	1.30**	-0.01	1.28**	0.84**	0.64*
	Lesson plan text	Postcourse lesson plans have a higher percentage of words related to cognitive processes and achievement than precourse lesson plans. Both pre- and postcourse lesson plans share similar frequently used words including the most frequently used technology-related words.						
Qualitative	Interviews	Participants with higher levels of TPACK elaborate on pedagogical practices, participate in opportunities to improve						

	their practice, and have a positive, yet nuanced perspective about teaching with technology. All interview participants were influenced by coursework, mentor teachers, professional development, internet resources, curricular resources, and content-area standards.

Note. *p < 0.05, **p < 0.01, † Participants not enrolled in an educational technology course.

What is the level of TPACK, reported and demonstrated, among graduate teacher education students? The presurvey mean scores indicate that the graduate students in the treatment group were confident in their ability to produce lessons in their content area, vary their teaching strategies, and plan the sequence of topics in their content area. Furthermore, they were confident in their ability to adjust their methods based on student performance, assist students in identifying conceptual connections in their content area, and anticipating misconceptions students may have about content-area concepts. In fact, the 10 highest mean item scores on the presurvey belonged to items related to PK, CK and PCK; the same three TPACK constructs with the highest subscale scores on the presurvey. The knowledge of teaching processes—methods and strategies (PK), knowledge of subject matter (CK) —and the knowledge of teaching process—methods and strategies specific to a subject matter (PCK) —are constructs key to teaching in traditional contexts. It is not surprising, then, that the treatment group reported a high ability on these items and constructs, because the group mostly comprised teachers with an average of 5.3 years of teaching experience, which is beyond the four years of experience at which gains in effectiveness tend to flatten out (Center for Education Policy Research, 2010).

The presurvey mean scores, however, did not indicate that the treatment group was confident in encouraging student interactivity with technology (TPK), moderating web-based student interactions (TPK), or predicting students' skills or understanding of a topic with technology (TPACK). Furthermore, they were wary about assisting students with troubleshooting technology (TK), integrating web-based courseware or applications (TCK), and troubleshooting hardware issues on their own (TK). The low confidence the preceding items was also reflected by the low construct mean scores of TPK, TK, and TPACK. These low construct scores support the hypothesis that there are teachers who continue to lack the knowledge and ability to work with various technologies (TK), to teach with technology (TPK), or teach a specific subject matter with technology (TPACK).

When compared to the treatment group, the presurvey mean scores for the control group indicate that the control group was confident in their abilities in similar areas. The control group reported high ability in planning the scope and sequence of topics in their content (CK) and in producing lessons in their content area (PCK). They also shared their confidence in their ability to adjust their methods based on student performance (PK). Unlike the treatment group, the control group did report higher ability in using technological representations to demonstrate content area concepts (TCK) and in addressing software issues (TK). The control group differentiated itself from the treatment group with the control group's highest scoring construct as TK. The control group shared two high constructs groups with the treatment group, PK and CK. As with the treatment group, the majority of the control group members were teachers who had 4.6 years of teaching experience, so the high reported ability in PK and CK is not surprising. The high reported ability in TK may be explained by members of the group who responded that they were enrolled in one or more educational technology courses during the course of the study. It may be that these members had more experience or training with technology than did the members of the treatment group.

The precourse lesson plan rubric mean scores indicate that the graduate students in the treatment group prepared lesson plans that included evidence of content knowledge (CK), clear lesson objectives (CK), appropriate teaching strategies (PCK), and meaningful content (PK). Just as with the presurvey, the treatment group demonstrated higher competence in items related PK, CK, and PCK. These three constructs were also the three highest subscale scores from the prelesson plan rubric. Again, high scores in these construct subscales and related items are not surprising given the characteristics of the treatment group. The consistency between the survey and rubric's high scoring subscales is a promising sign of construct validity.

The precourse lesson plan rubric mean scores, however, did not indicate that the treatment group prepared lesson plans that provided a rational the technology used (TK), provided a rationale for the specific technology choice featured in the lesson (TPK), demonstrated understanding of technology (TK), or used technologies that enhance teaching methods (TPK). These items were related to two of the three subscales with the lowest scores, TK and TPK. The third lowest subscale score was TPACK. These three subscales matched the low scoring subscales on the presurvey as well, which provides more evidence for instrument construct validity.

Do TPACK levels, reported and demonstrated, change after participation in an educational technology course? The treatment group saw all mean item and subscale scores increase from pre- to postsurvey with all but five items making statistically significant increases. Items related to implementing technology to support teaching methods (TPK), creating effective representations with technology (TCK), and moderating web-based student interactivity (TPK) making the largest increases. All of the subscale mean score increases were significant with the largest increases seen in TCK, TPK, and TPACK, which had effect sizes that ranged from 0.61 to 1.14. The medium to large increases seen in these subscale scores reflect the focus of the course on changing how content is represented with technology (TCK), teaching with technology (TPK), and teaching a specific subject matter with technology (TPACK). This suggests that the course was effective in meeting its learning goals.

The smallest and nonsignificant increases were items related to producing lessons with an appreciation for the topic (PCK), adjusting methods based on student performance (PK), and addressing software issues (TK). The three subscale scores with the smallest, yet significant, gains were PK, PCK, and TK. Again, these results are consistent with the goals of the course, because it was not focused on general pedagogy, content-specific pedagogy, or the technical aspects of hardware or software.

Two item mean score increases from the control group's pre- and postsurvey were significant. The items were related to distinguishing appropriate problem solving attempts by students (PCK), and to building student knowledge and skills with technology (TPK). The increases on the PCK and TPK subscales were also significant with medium effect sizes. Because the control group members were education graduate students, most of whom were teachers and enrolled in various education courses, it would not be surprising to see significant increases in PK, CK, or PCK. The significant increase in TPK was surprising, at least initially. The courses that the control group members could potentially be enrolled in included educational technology courses. In fact, nine members of the control group were enrolled in an educational technology course during the semester the surveys were administered. Excluding these nine members from analyses did not result in significant differences from pre- to postsurvey for any items or subscales. This result suggested that the members enrolled in the educational technology courses accounted for the significant increases in TPK and PCK. The results above in conjunction with the results that suggest the presurvey subscale scores between the treatment and control group were not significantly different. Taken together, it is possible to conclude that participation in an educational technology course contributed to the significant increases in the treatment groups TPACK item and subscale survey scores.

All mean item rubric item scores increased significantly from pre- to postsurvey for items related to TK, TPK, TCK, and TPACK. Items related to student-centered technology (TPK), providing a rationale for integrating technology (TK), integrating technology (TK), and implementing technologies that enhance teaching methods (TPK) had the largest increases. Effect sizes for the significantly different subscale scores ranged from 0.57 to 1.26. Similar to the survey findings, the medium to large increases seen in these subscale scores reflects the learning goals for the educational technology course and suggests that the course was effective. Furthermore, the survey and rubric measured large gains on the same subscales, excluding TK from the rubric. This result provides additional evidence for the measures' construct validity. The discrepancy between the two measures in TK scores can be explained by the different focus of the TK items. While the rubric measures TK largely by the inclusion of technology in the lesson plan, the survey measures the ability to troubleshoot technical issues. The nonsignificant differences from pre- to postrubric scores found in items related to PK, CK, and PCK also reflected the course goals were.

Are self-reported levels of TPACK evident in artifacts of teacher practice? Previous results showed that high scoring and low scoring TPACK constructs as a group were measured similarly between the survey and lesson plan rubric. Furthermore, the survey and rubric both saw the same group of constructs with the highest gain from pre- to postcourse. These results seemed to pave a path toward convergent construct validity between the two measures; however, there was only one significant construct correlation between the presurvey scores and precourse rubric scores. Similarly, the postsurvey scores and postcourse rubric scores revealed only three significant construct correlations. The significant correlation pairs on both the premeasure (presurvey PK with prerubric TCK) and postmeasure (postrubric TK with postsurvey PK, CK, and PCK) were not interpretable. If the survey and rubric were measuring the same constructs, high and significant correlations would be expected along the diagonal of the correlation matrix (e.g., survey PK with rubric PK) demonstrating convergent validity. Within the TPACK framework, there is no theoretical explanation for a relationship between PK and TCK or why TK would be related to PK, CK, or PCK. Although both instruments' measures of the preliminary state and growth of the treatment group were consistent with previous research and the learning goals of the course, these correlation results suggest that the survey and rubric have poor convergent validity. Many researchers have developed new TPACK measures (Koehler, Shin, & Mishra, 2011), but little work has been done to cross-validate these measures.

How does the language differ between artifacts developed before the course and artifacts developed at the end of the course? Postcourse lesson plans were found to use more words and a higher percentage of verbs than the precourse lesson plans. The raw word count differences are not a practical finding, because the postcourse lesson plans were developed as a final project; therefore, participants likely included more detail than they typically would for a lesson plan they would prepare for classroom use (Harris, Grandgenett, & Hofer, 2010). The higher percentage of verbs used in the postcourse lesson plans could be related to a higher percentage of lesson plan objectives or a higher percentage of teacher or student activities. The higher percentage of verb usage is likely related to more detailed postcourse lesson plans. The postcourse lesson plans also featured a higher percentage of words related to cognitive processes (cause, know, ought) and achievement (earn, hero, win). The increase in words related to cognitive processes could be related to lessons that were planned to elicit higher order thinking skills from students and that were more student-centered. The increase in words related to achievement could be related to teachers attempting to invest their students in academic success or to teachers collecting achievement data from their students to make data-driven instructional decisions.

When examining individual word frequencies from the pre- and postlesson plans, similarities in word usage emerge more often than differences. Both groups of lesson plans frequently used nouns and verbs like *student*, *class*, *group*, *teacher*, *use*, *create*, and *make*. These frequently used nouns and verbs suggest that the lessons are focused on individual or small group work where students use, create, and make products to demonstrate their learning. The words conjure the image of a student-centered classroom with a constructivist or constructionist teacher guiding the learning. The consistency in these words from pre- to postlesson plan was not surprising. Just as it would be unexpected for an educational technology class to affect measures PK, CK, and PCK, it was also unlikely that these types of words would change after participation in an educational technology class as the words are core to describing teacher and student actions in the classroom. With the measured changes in TK, TCK, TPK, and TPACK from pre- to postlesson plan, it should be expected that the use of technology-related words would change. However, the top three technology-related words, *video*, *computer*, and *technology* were the same for both groups of lesson plans. While the graduate students are writing the same technologies into their postlesson plans as they did in their prelesson plans, the rubric gains suggest that the graduate students are planning to teach with these technologies in more effective ways. Although the graduate students were introduced to new technologies during the course of the semester, implementing new technologies and new teaching methods simultaneously may not be the best practice. Making changes to either the content of the lesson, the methods, or the technology makes sense when still in the development phase of acquiring new knowledge, skills, and abilities.

Unlike raw word counts, collocation tables list the words that commonly appear within five words of the key word. These tables provide context to the key word and they help to define what the key word means in context. Collocation tables show that students were the center of attention and are constantly in action. Much of the time the students were using some tool, including technology or a process, to complete a task. Particularly in relation to describing student action, the verb of choice was *use*. *Use* is a generic verb that has little meaning by itself, and it requires surrounding words and context to clarify meaning. Sentences in lesson plans with *use* as the verb place an inappropriate focus on tools and processes rather than the tasks to be accomplished. The following are two examples of these types of sentences: “The students will use the internet and a Word document to record and produce their children’s book” and “This strand requires students to use digital media and environments to communicate and collaborate with others.” These sentences suffer from being techno-centric and suggest that the purpose of the activities described is simply to use the technology rather than to produce, communicate, or collaborate. Rewritten, the sentences take on a new focus with enhanced meaning: “The students will record and produce their children’s book with the internet and a Word document” and “This strand requires students to communicate and collaborate with others through digital media and environments.” The popularity of *use* when describing student actions or lesson objectives may be an artifact of the techno-centric instruction and professional development the graduate students have engaged in or may simply be a semantic preference.

In both groups of lesson plans, the most frequently written technology-related words were *video*, *computer*, and *technology*, and the collocated words suggest that technology was integrated in promising ways by placing it in the hands of students to create products and with explicit connections to standards, but may still be one step removed from the classroom. Students were creating, uploading, and watching videos, and teachers were connecting technology-related lesson objectives and student activities with curriculum standards. The contexts suggest that teachers were implementing best practices when integrating technology, which is an encouraging finding. However, words collocated with *computer* suggest that teachers and students do not have access to computers in their own classroom and must visit a school computer lab to complete technology-infused lessons. This finding is supported by a meta-analysis by Hew and Brush (2007) that found that a lack of resources (technology, access to technology, time, or technical support) was the most frequent barrier to integrating educational technology.

Exploring the network of words through a co-occurrence network diagram provided a visual display that corroborates the findings from raw word counts and collocation statistics: students and student learning were at the center of lesson plans surrounded by clusters of activities. Care should be taken in drawing definitive conclusions from the patterns of the co-occurrence network. The lesson plan corpus was relatively small, so communities in the network tended to be from a single lesson plan. This is most evident in the precourse lesson plan network. With a larger lesson plan corpus, the co-occurrence network may be able to form communities from across lesson plans so that general trends within the corpus could emerge.

How do students with higher levels of TPACK differ from those with lower levels of TPACK? Answering this question aids in building characteristic profiles of students who enter an educational technology course with higher ability in the seven TPACK constructs and those students who demonstrate the most growth. For an instructor, the knowledge of a student's age, gender, hours of professional technology use, and self-reported knowledge of pedagogy, content, and educational technology could aid in adjusting the course to the strengths and weaknesses of students.

Before the course, female graduate students reported initial higher ability in PK and CK, while males reported higher ability in TK and TPK on the survey, and while females demonstrated higher levels of TK, TPK, TCK, and TPACK on their initial lesson plans. Following the course, there were no significant differences between the genders. These observed gender differences related to TPACK constructs were likely unique to this sample, but it appears that participation in an educational technology course can close gender gaps in TPACK constructs.

Younger graduate students (21 to 29 years old) are likely to enter a course with higher reported ability in TK than older graduate students (50 to 59 years old) and this difference persists even after participation in the course. This finding reinforces the stereotype that older teachers are less adept at using technology. Additionally, graduate students with more teaching experience reported higher levels of PK and demonstrated higher levels of TK. Some consideration of age and teaching experience should be taken when developing a course for graduate students, but the two characteristics do not have an impact on the constructs that would be included in a typical educational technology course like TCK, TPK, and TPACK.

Upon completion of the course, graduate students who describe their knowledge of pedagogy as intermediate or advanced had higher reported PK, CK, and PCK ability than those who describe their knowledge as beginner. Graduate student who described their knowledge of educational technology as intermediate or advanced have higher reported ability than beginners in CK, TK, TCK, and TPACK. Various reported levels of knowledge of a content area did not have any relationship with TPACK constructs.

Levels in knowledge of pedagogy, content, and educational technology were also related to the reported growth a student experiences in the seven TPACK constructs. Graduate students with advance knowledge of pedagogy have higher reported gains in

CK and PCK than pedagogy beginners. Students with advance knowledge of content have higher reported gains in PCK than beginners. Students with intermediate knowledge of education technology have higher gains in PK, CK, TCK, and TPK than educational technology beginners. If a graduate-level course instructor needs to get a feel for the TPACK abilities among a group of students for the purposes of tailoring the course, then asking students to provide their level of knowledge of pedagogy, content, and educational technology would be a simple way to gather that information.

The number of credit hours taken in pedagogy, content, and technology related courses were related to reported levels of TPACK constructs, but not related to demonstrated levels of TPACK from lesson plans. Students with more credit hours in pedagogy reported higher levels of PCK and TPACK. Students with more credit hours in content reported higher levels of PK and TPACK. Students with more credit hours in technology reported higher levels of PK, CK, PCK, and TPACK. The number of hours per day spent using technology for professional purposes was a significant predictor for all reported levels of all TPACK constructs, but not for any demonstrated TPACK constructs in lesson plans.

Graduate students who participated in the interview group that tended to have higher TPACK scores were those that had more teaching experience in permanent positions and were able to elaborate on their pedagogical practices, citing specific frameworks that they used to structure lessons. They also participated in professional development, enrolled in formal courses, sought out curricular resources, and collaborated with colleagues to improve their practice. The students also had a long standing affinity for their subject area along and could describe instances where they saw effective uses of technology in their subject area and could describe their own teaching with technology and rationale for using technology. Finally, the students interviewed had a positive, yet nuanced attitude about technology's potential impact on teaching. They thought that technology had its place in certain contexts but was not a panacea for all learning problems. Unfortunately, students cited increased engagement as the primary benefit for teaching with technology. This is problematic because engagement is not well defined for teachers, it is difficult to measure, and it is not directly connected to learning standards and objectives. Teacher educators need to help teachers discuss the benefits of technology in concrete terms that describe student outcomes. Overall, the interviews helped to uncover the qualitative differences among participants that contributed to their measured TPACK ability.

What teaching and learning experiences influenced students' knowledge of and practice in teaching? The graduate students selected for interviews followed a largely traditional path to teaching by completing an undergraduate teacher preparation program. The courses, instructors, textbooks, and their mentor teachers in their student teaching experience were the first big influence on their teaching. In their positions as full or part-time teachers, they were influenced by internet resources, curricular resources they sought out for their classes, and the standards outlined for their subject area. Additional significant influences on their teaching were district or school professional development, standardized curriculum adopted by their district or school, and their colleagues. As all the students were currently enrolled in a graduate program, they cited their graduate courses as recent influences on their teaching. This finding in particular contributes evidence that participation in an educational technology course influenced knowledge and ability in TPACK.

Limitations

As with any study, this research is not without limitations. Both the treatment group and control group were selected as intact classroom and therefore may not be representative of the population of graduate students who enroll in an educational technology course. It is therefore important not to generalize the results of this study to dissimilar populations. Furthermore, the interview participants were selected based on their presurvey score, but not all those who were selected agreed to participate. This self-selection could have impacted the conclusions drawn from the interviews because the interview participants could be reliably different from the other participants in the study.

The measurement of TPACK relied on reliable instruments from peer-reviewed studies; however, the measurement of TPACK is an emerging field and these instruments were not cross-validated. Construct validity could be compromised by the fuzzy definitions of constructs in the TPACK framework and by the measures based on those definitions. Results suggested that neither the survey nor the rubric adequately discriminated among the TPACK constructs. Furthermore, survey research relies on self-report and is susceptible to presentation bias. Similarly, lesson plans scored with a rubric are a suitable proxy for teacher practice, but do not replace observations of teacher behavior in the classroom. Therefore, the measures may not represent the graduate students' true knowledge, ability, and practice. Multiple raters were used to score lesson plans to enhance the internal validity and reliability of the lesson plan scores, however the two groups of raters could have been reliably different impacting the scores on the group of precourse lessons and postcourse lessons.

Because this was a field study where the researcher has less control than in a laboratory-based study, participant attrition was a limitation as some participants did not respond to or provide artifacts for one or more measures in the study. The students' non-participation was likely not random; therefore, their absence could contribute to the observed results. Participant attrition may have also affected statistical power, particularly in relation to the analyses of lesson plan rubric scores. Although statistical tests that compensate for the potential for Type I error were used (e.g., Dunnett's test), this study could have suffered from an error rate problem due to the large number of statistical tests performed.

Implications

The findings in this study primarily have implications for graduate teacher preparation program educational technology course offerings and how educational technology course instructors adjust instruction based on their knowledge of students. Secondarily, the findings have implications for the field of TPACK measurement and research.

This study suggests that graduate students who are current teachers have the skills and ability necessary for teaching in traditional contexts. They do not, however, have the skills and ability to teach effectively in technology-rich environments. This study also suggests that stand-alone educational technology courses are effective in facilitating growth in TPACK constructs. If teacher education programs agree that teaching teachers to teach effectively with technology is an important program goal, educational technology courses should continue to be offered.

Although the group of participants in this study may not be representative of the population of graduate students who enroll in educational technology courses, it is safe to assume that graduate students who do enroll in these courses have a broad range of knowledge, skills, and experience. It is important for an instructor to know this information about their students so that appropriate adjustments in the course can be made to meet student needs. It is impractical for instructors to run their students through a battery of measures to determine knowledge, skills, and ability relevant to the course and then analyze the results. This study identified student characteristics that have significant relationships with TPACK construct levels.

TPACK is an incredibly fertile area of exploration in educational technology and teacher education. Since the introduction of the framework less than a decade ago, hundreds of articles, proceedings papers, presentations, and dissertations explored some facet of TPACK (Koehler, 2013). Koehler et al. (2011) identified 66 journal articles, conference proceedings, dissertations, and a presentation that gathered data on TPACK in a systematic manner. The number falls to 24 by narrowing the focus to empirical studies that appeared in peer-reviewed journals and investigated teachers' TPACK prior to 2012, with the bulk published in 2010 and 2011 (Wu, 2013). This series of decreasing numbers represents, at the same time, the enormous popularity of TPACK and the complexities in measuring the construct. The knowledge required to teach effectively with technology is complex and the framework that describes that knowledge is complex, so it follows that measuring that knowledge through the TPACK lens is also complex. This complexity is not only manifested in the number of publications, but also the lack of evidence of reliability and validity reported. Koehler et al. (2011) found that 69% of the studies they analyzed did not provide any evidence of reliability, and 90% of the studies provided no evidence of validity for the measurement methods use.

This current study provided evidence of internal consistency and test/retest reliability for both the survey and the rubric. This study also provided evidence for discriminant and convergent validity within and between the two instruments. While the instruments demonstrated acceptable levels of reliability, they did not demonstrate adequate convergent or discriminant validity. The evidence from this study and the lack of evidence from other studies regarding the validity of TPACK instruments point to the necessity for the TPACK research community to spend significant time and resources on validation studies. Because 88% of TPACK studies evaluated by Koehler et al. (2011) measured TPACK with more than one instrument, cross-validation studies are particularly important.

Recommendations

At minimum, a single standalone educational technology course designed to teach general technological pedagogies (TPK) should be offered. This is the traditional educational technology course model. A more ideal situation would be a sequence of three courses, each a prerequisite for the following course. The first course would focus on building technology knowledge (TK) and skills—in essence, a digital literacy course designed for teachers. The second course would focus on developing general technological pedagogies (TPK) similar to most extant educational technology courses. The third course would focus on developing content-specific technological pedagogy

(TPACK) and content-specific technology knowledge and skills (TCK). Given the current environment in which general educational technology course are being eliminated from undergraduate teacher education programs, this three course offering is unlikely. Perhaps this type of course sequence could be more easily built into an educational technology master's or certificate program.

Instructors can infer student TPACK levels by gathering common demographic information (age, gender, years of experience), self-reported knowledge of pedagogy, content, and educational technology, and hours of technology use for professional purposes. For example, a instructor could find that a group of students was mostly older women with more than 6 years of teaching experience, high reported knowledge in pedagogy and content, low reported knowledge in technology, and few hours of professional technology use. Based on this student information and the results of this study, the instructor could infer that the group would be strong in PK, CK, and PCK, but may struggle in TK, TCK, TPK, and TPACK. With this data, the instructor could then adjust the course accordingly.

Future Research Directions

Although many reports on TPACK and its relation to teacher education have been written, presented, and discussed in recent years, there is still much research to be done. TPACK, although based on an established theoretical framework, is still in its infancy given that less than a decade has passed since its introduction. As Graham (2011) clearly described, TPACK has experienced little theoretical development resulting in various construct definitions and opaque boundaries between those constructs. He suggest that researchers address the issues through investigations of the elements of the theory (factors, constructs or concepts), how the elements are related, and why the elements and relationships among them are important in the context of teaching with technology (Graham, 2011). The primary obstacles to overcome in identifying the elements of the theory include the clarity of TPACK's foundational theory (PCK), the complexity of the TPACK framework, and the imprecise definitions for elements in the framework (Graham, 2011). Coming to a consensus on whether TPACK (the core construct) is a mixture of all the elements or a synthesis of those elements as well as defining boundaries between elements are fundamental to investigating the relationships between the elements. Articulating the importance of TPACK involves describing the value it adds over and above PCK and how TPACK contributes to the study of teaching with technology (Graham, 2011).

TPACK instrument development and validation studies along with investigations into how preservice and inservice teachers (including graduate students) best learn to teach with technology are two types of studies that may address the issues with TPACK raised by Graham (2011). A large-scale instrument development and validation study could investigate the first two issues raised, the elements of the framework, and how they are related. The TPACK framework, as originally conceived, consists of seven constructs, yet outside of self-report survey instruments, few instruments measure all seven constructs. With the development of new or modified lesson plan rubric and classroom observation protocols, an instrument validation study that incorporates a self-report survey, a rubric, and a classroom observation protocol that each measure all seven TPACK constructs could be conducted. The study would require a large sample size of preservice and/or inservice teachers to conduct a confirmatory factor analysis that would provide evidence of construct, convergent, and discriminant validity. Further evidence of convergent validity could come from significant correlations between the same construct subscales on each of the three instruments. Additional discriminant validity evidence could be demonstrated by low and nonsignificant correlations among construct subscales within an instrument.

To address the issue of why the elements of TPACK and their relationships are of importance to teaching with technology, an investigation into how preservice and inservice teachers best learn to teach could be conducted. An ongoing debate exists within teacher education related to how best to produce teachers who use technology in content-specific and pedagogically effective ways. The literature reports a variety of strategies, but the results are conflicting and poorly evaluated (Kay, 2006; Mims, Polly, Shepherd, & Inan, 2006). For inservice teachers, the most popular strategy is one in which no specific technology class is offered and technology is integrated into each teacher education program course (Kay, 2006). The second most popular strategy is to offer a single educational technology course that focuses on technological skills (Kay, 2006). Training of inservice teachers is not well documented. However, Robinson (2002) found that preservice and inservice teachers differed in their effectiveness perception ratings of eight different training methods. This suggests that the method most effective for one teacher group may not be the most effective for another teacher group.

Although the literature reviews many types of methods to teach preservice and inservice teachers how to teach effectively with technology, there is a lack of evidence that suggests what method is the most effective. Within the contexts of TPACK and cognitive load, this problem is defined by the path choices available and the cognitive load associated with each of the path choices. These choices include delivering instruction focused on: (a) TPK first, followed by TPACK, (b) PCK followed by TPACK, or (c) only TPACK. Graham (2011) stated that the optimal path may be determined by teacher type and he suggested several hypotheses. One hypothesis was that it may be "more effective to learn content-specific pedagogies and supporting technologies simultaneously" (Graham, 2011, p. 1959), which would be a TPACK-only option. Another hypothesis was that preservice teachers would benefit from a TPK to TPACK path due to the cognitive load associated with learning new technologies and content pedagogies simultaneously (Graham, 2011). Finally, he stated that inservice teachers may benefit from the PCK to TPACK path due to their prior knowledge of content pedagogies (Graham, 2011).

It would be impractical to develop three different courses, course sequences, or professional development workshops to test these paths, at least in the initial iteration of the study. A pilot study could run participants through three computer-based modules in a lab environment. The three computer-based modules would be differentiated by the path the modules take to reach the terminal learning goal. Pre- and posttests would be developed to measure the module objectives. The generalizability of the study would be limited in that it would not faithfully recreate the contexts in which preservice and inservice teachers are taught to teach with technology; however, the results of the study could lead to a more ambitious field-based study.

Conclusion

As educational technology continues to find its way into classrooms, it is important that teachers know how to teach effectively with technology. The expectations placed on technology to affect change in education are driven, in part, by the significant investment schools have made. Despite evidence that suggests that teaching with technology facilitates learning, the expectations continue to outstrip the results. A possible explanation for technology's small but significant effect on learning is ineffective implementation by teachers unfamiliar in teaching with technology. Teacher education programs have sought various means to improve teachers' technology skills, and one framework for doing so is TPACK.

This study's mixed-methods research design helped to provide a fuller understanding of TPACK development and change over time in graduate teacher education students; an important, but underrepresented teacher group in education research. Both quantitative and qualitative results showed that students are relatively weak in teaching with technology, but that their perceived and demonstrated ability in teaching with technology can be improved. Results also showed that TPACK ability levels vary significantly by student characteristics and that students are influenced in their development by a mentors, colleagues and curricular resources.

The findings from this study could be used to guide teacher preparation programs and researchers interested in measuring and developing TPACK. Teacher preparation programs should evaluate how they prepare their teachers to teach with technology and use the results of this study as a jumping-off point to find more effective and efficient ways to prepare their teachers. TPACK research continues to grow while still in its early phases of investigation. TPACK researchers should recognize that tight construct definitions and valid and reliable instruments are required if TPACK is to have a meaningful impact on teacher education. Further investigations of TPACK's elemental relationships, the importance of those relationships and the impact of those elements and relationships on teacher education are needed.

REFERENCES

Akcaoglu, M., Kereluik, K., & Casperson, G. (2011). Refining TPACK rubric through online lesson plans. *Society for Information Technology & Teacher Education International Conference 2011*, *2011*(1), 4260–4264.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, *55*(4), 1656–1662. doi:10.1016/j.compedu.2010.07.009

Archambault, L., & Crippen, K. (2009). Examining TPACK among K-12 online distance educators in the United States. *Contemporary Issues in Technology and Teacher Education*, *9*(1), 71–88.

Aud, S., Hussar, W., Kena, G., Bianco, K., Frohlich, L., Kemp, J., & Tahan, K. (2011). *The condition ofeEducation 2011* (No. NCES 2011-033). Washington, DC: U.S. Government Printing Office: U.S. Department of Education, National Center for Education Statistics. Retrieved from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2011033

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of pedagogical content knowledge. In N. G. Lederman & J. Gess-Newsome (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education*, (pp. 3–16). Science & Technology Education Library London: Kluwer Academic.

Bloom, B. S. (1968). Learning for Mastery. Regional Education Laboratory for the Carolinas and Virginia, Mutual Plaza (Chapel Hill and Duke Sts.), Durham, N.C. 27701. Retrieved from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED053419

Brantley-Dias, L., Kinuthia, W., Shoffner, M. B., de Castro, C., & Rigole, N. J. (2007). Developing pedagogical technology integration content knowledge in preservice teachers: A case study approach. *Journal of Computing in Teacher Education*, *23*(4), 143–150.

Brown, D. (2006). Can instructional technology enhance the way we teach students and teachers? *Journal of Computing in Higher Education*, *17*(2), 121–142.

Browne, J. (2009). Assessing pre-service teacher attitudes and skills with the technology integration confidence scale. *Computers in the Schools*, *26*(1), 4–20.

Caspi, A., Roberts, B. W., & Shiner, R. L. (2005). Personality development: stability and change. *Annual Review of Psychology*, *56*, 453–84. doi:10.1146/annurev.psych.55.090902.141913

Center for Education Policy. (2010). *Teacher employment patterns and student results in Charlotte Mecklenburg schools*. Cambridge, MA.

Christensen, R. W., & Knezek, G. A. (2009). Construct validity for the teachers' attitudes toward computers questionnaire. *Journal of Computing in Teacher Education*, *25*(4), 143–155.

Clauset, A., Newman, M. E., & Moore, C. (2004). Finding community structure in very large networks. *Physical review E*, *70*(6), 066111.

Cochran-Smith, M., & Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. *Review of research in education*, *24*, 249-305.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. London: Psychology Press.

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design & analysis issues for field settings*. Boston, MA: Houghton Mifflin.

Cox, S. (2008). *A conceptual analysis of technological pedagogical content knowledge* (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses.

Creswell, J., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Los Angeles, CA: SAGE Publications.

Curts, J., Tanguma, J., & Pena, C. M. (2008). Predictors of Hispanic school teachers' self-efficacy in the pedagogical uses of technology. *Computers in the Schools*, *25*(1–2), 48–63.

Dawson, K., Ritzhaupt, D. A., Liu, F., Rodriguez, M. P., & Frey, A. C. (in press). Using TPCK as a lens to study the practices of math and science teachers involved in a year-long technology integration initiative. *Journal of Computers in Mathematics and Science Teaching*.

Driscoll, M. P. (2004). *Psychology of Learning for Instruction* (3rd ed.). Boston, MA: Allyn & Bacon.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.

Franklin, C. (2007). Factors that influence elementary teachers use of computers. *Journal of Technology and Teacher Education*, *15*(2), 267–293.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. In N. G. Lederman & J. Gess-Newsome (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 3–16). Science & Technology Education Library. London: Kluwer Academic.

Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*(3), 1953–1960. doi:16/j.compedu.2011.04.010

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of inservice science teachers. *TechTrends*, *53*(5), 70–79. doi:10.1007/s11528-009-0328-0

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. Professional development and practice series. New York, NY: Teachers College Press, Teachers College, Columbia University.

Groth, R., Spickler, D., Bergner, J., & Bardzell, M. (2009). A qualitative approach to assessing technological pedagogical content knowledge. *Contemporary Issues in Technology and Teacher Education*, *9*(4), 392–411.

Harris, J. B., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment rubric. *Society for Information Technology & Teacher Education International Conference 2010*, *2010*(1), 3833–3840.

Harris, J. B., Mishra, P., & Koehler, M. (2009). Teachers' technological pedagogical content knowledge and learning activity types: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, *41*(4), 393–416.

Hew, K., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: current knowledge gaps and recommendations for future research. *Educational Technology Research & Development*, *55*(3), 223-252.

Higuchi, K. (2012). *KH coder*. Kyoto, Japan: Ritsumeikan University. Retrieved from http://khc.sourceforge.net/en/

Hofer, M., & Grandgenett, N. (2012). TPACK development in teacher education: A longitudinal study of preservice Teachers in a secondary M.A.Ed. program. *Journal of Research on Technology in Education*, *45*(1), 83–106.

Hogarty, K. Y., Lang, T. R., & Kromrey, J. D. (2003). Another look at technology use in classrooms: The development and validation of an instrument to measure teachers' perceptions. *Educational and Psychological Measurement*, *63*(1), 139-

162.

International Society for Technology in Education. (2000). *ISTE national educational technology standards and performance indicators for teachers*. Washington, DC: International Society for Technology in Education.

Ivankova, N. V., Creswell, J. W., & Stick, S. L. (2006). Using mixed-methods sequential explanatory design: From theory to practice. *Field Methods, 18*(1), 3–20. doi:10.1177/1525822X05282260

Kay, R. (2006). Evaluating strategies used to incorporate technology into preservice education: A review of the literature. *Journal of Research on Technology in Education, 38*(4), 383–408.

Keenan, T., & Evans, S. (2009). The Principles of Developmental Psychology. *An introduction to child development* (pp. 3–20). London: SAGE Publications.

Kereluik, K., Casperson, G., & Akcaoglu, M. (2010). Coding pre-service teacher lesson plans for TPACK. *Society for Information Technology & Teacher Education International Conference 2010, 2010*(1), 3889–3891.

Kline, P. (2000). *The handbook of psychological testing*. Psychology Press.

Koehler, M. J. (2013). TPACK bibliography. *TPACK.org*. Retrieved May 26, 2013, from http://www.matt-koehler.com/tpack/tpack-bibliography/

Koehler, M. J., Shin, T. S., & Mishra, P. (2011). How do we measure TPACK? Let me count the ways. In R. N. Ronau, C. R. Rakes, & M. L. Niess (Eds.), *Educational technology, teacher knowledge, and classroom impact: A research handbook on frameworks and approaches* (pp. 16–31). Hershey, PA: Information Science Reference.

Kramarski, B., & Michalsky, T. (2010). Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge. *Learning and Instruction, 20*(5), 434–447. doi:10.1016/j.learninstruc.2009.05.003

Kuhn, T. S. (1970). The structure of scientific revolutions. Chicago, IL: The University of Chicago Press.

Lemke, C., Coughlin, E., & Reifsneider, D. (2009). *Technology in schools: What the research says: An update*. Culver City, CA: Metiri Group commissioned by Cisco.

Lewins, A., & Silver, C. (2007). *Using software in qualitative research: A step-by-step guide*. Thousand Oaks, CA: Sage Publications Ltd.

MacDonald, R. (2009). Supporting learner-centered ICT integration: The influence of collaborative and needs-based professional development. *Journal of Technology and Teacher Education*, *17*(3), 315-348.

Machado, C., Laverick, D., & Smith, J. (2011). Influence of graduate coursework on teachers' technological, pedagogical, and content knowledge (TPACK) skill development: An exploratory study. *Society for Information Technology & Teacher Education International Conference 2011*, *2011*(1), 4402–4407.

Mims, C., Polly, D., Shepherd, C., & Inan, F. (2006). Examining PT3 projects designed to improve preservice education. *TechTrends*, *50*(3), 16–24.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054.

Pennebaker, J. W., Booth, R. J., & Francis, M. E. (2007). *LIWC: Linguistic inquiry and word count*. Austin, TX: University of Texas Austin. Retrieved from http://www.liwc.net/

Reiser, R. A. (2001). A history of instructional design and technology: Part I: A history of instructional media. *Educational Technology Research and Development*, *49*(1), 53–64. doi:10.1007/BF02504506

Robinson, L. (2002) *Perceptions of preservice educators, inservice educators, and professional development personnel regarding effective methods for learning technology integration skills*. A dissertation presented to University of North Texas, Denton, TX.

Roblyer, M. D., & Doering, A. H. (2009). Integrating educational technology into teaching. Pearson, Boston.

Romesburg, H.C. (1984). *Cluster analysis for researchers*. Lifetime Learning Publications, Belmont, CA.

Schacter, D. L. (1999). The seven sins of memory: Insights from psychology and cognitive neuroscience. *American psychologist*, *54*(3), 182.

Schmidt, D., Baran, E., Thompson, A., Koehler, M., Punya, M., & Shin, T. (2009a). Examining preservice teachers' development of technological pedagogical content knowledge in an introductory instructional technology Course. *Society for Information Technology & Teacher Education International Conference 2009*, *2009*(1), 4145–4151.

Schmidt, D. A., Baran, E., Thompson, A. D., Mishra, P., Koehler, M. J., & Shin, T. S. (2009b). Technological Pedagogical Content Knowledge (TPACK): The development and validation of an assessment instrument for preservice teachers. *Journal of Research on Technology in Education*, *42*(2), 123–149.

Schwarz, N., & Sudman, S. (1994). *Autobiographical memory and the validity of retrospective reports*. New York, NY: Springer-Verlag.

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, *86*(2), 420–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18839484

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

Tashakkori, A., & Creswell, J. W. (2007). Exploring the nature of research questions in mixed methods research. *Journal of Mixed Methods Research*, *1*(3), 207–211. doi:10.1177/1558689807302814

Tashakkori, A., & Teddlie, C. (2003). *Handbook of mixed methods in social & behavioralrResearch*. Thousand Oaks, CA: SAGE Publications.

United States Department of Education. (n.d.). Preparing tomorrow's teachers to use technology program (pt3). Retrieved from http://www2.ed.gov/programs/teachtech/index.html

United States Department of Education. (2011). Licensing and certification requirements. Retrieved October 14, 2011, from http://teach.gov/become-teacher/licensing-and-certification/

Wellings, J., & Levine, M. H. (2009). *The digital promise: Transforming learning with innovative uses of technology*. New York, NY: Joan Ganz Cooney Center at Sesame Workshop. Retrieved from http://www.joanganzcooneycenter.org/Reports-26.html

Wu, Y.T. (2013). Research trends in technological pedagogical content knowledge (TPACK) research: A review of empirical studies published in selected journals from 2002 to 2011. *British Journal of Educational Technology*, *44*(3), E73–E76. doi:10.1111/j.1467-8535.2012.01349.x

APPENDIX A

TPACK SURVEY

The following survey items are intended to gather information about your background and experience/knowledge regarding the use of technology in the classroom. Please select the response that best describes you.

1. What is your name? (PLEASE NOTE: ALL responses will remain strictly confidential and will be used to evaluate EDT 530)

2. Are you male or female?
- Male
- Female

3. Please provide your age.

4. What grade level(s) do you teach? (Select all that apply).
What grade level(s) do you teach? (Select all that apply).
- Elementary (K-5)
- Middle (6-8)
- High School (9-12)
- Higher Education
- I am not currently teaching.

5. Including this school year, how many years of experience do you have as a K-12 teacher? (Include years spent teaching both full and part time, in both public and private schools.)

6. If you are a current or former classroom teacher, how would you classify your content area? (Please select all that apply). If you are not a teacher, please select the content area(s) with which you most closely identify.
- Math
- Science
- English/Language Arts
- Social Studies
- Foreign Language
- English Language Learning
- Art/Music
- Electives
- Other (please specify)

7. What type of educational degree do you hold? Please select only the degree(s) you hold that are education related. Select all that apply.
- Bachelor's
- Master's
- Ph.D
- Ed.D

- None

8. What degree are you currently pursuing?
   - Bachelor's
   - Certificate
   - Master's
   - Ed.D
   - Ph.D

9. In what program are you currently enrolled? Please select from the drop-down menu below.

10. How many credit hours have you completed specific to your content area (e.g., math, science, social studies, elementary) when completing your education-related degree(s)? Please type the number of credit hours.

11. How many credit hours have you completed related to technology (both general technology skills and educational technology/technology integration) while completing your education-related degree(s)? Please type the number of credit hours.

12. How many credit hours have you completed related to general or content-specific pedagogy while completing your education-related degree(s)? Please type the number of credit hours.

13. How many hours per day do you spend using technology for personal purposes? Please type the number of hours per day.

14. How many hours per day do you spend using technology for professional purposes? Please type the number of hours per day.

15. How many hours of reading, researching or learning about educational topics do you spend per month that is not related to academic classes or in-service training? Please type the number of hours per month.

16. Overall, how would you describe your knowledge of educational technology ?
    - Beginning
    - Intermediate
    - Advanced
    - Expert

17. Overall, how would you describe your knowledge of pedagogy?
    - Beginning
    - Intermediate
    - Advanced
    - Expert

18. Overall, how would you describe your knowledge of your content area?
- Beginning
- Intermediate
- Advanced
- Expert

19. For each of the statements below, please indicate your level of abilty in the following areas. Please indicate whether your ability is poor, fair, good, very good, or excellent for each statement.

Poor Fair Good Very Good Excellent

a. My ability to troubleshoot technical problems associated with hardware (e.g., network connections).
b. My ability to create materials that map to specific district/state standards.
c. My ability to use a variety of teaching strategies to relate various concepts to students.
d. My ability to decide on the scope of concepts taught within in my class.
e. My ability to use the results of technology-based assessments to modify instruction.
f. My ability to distinguish between correct and incorrect problem solving attempts by students
g. My ability to address various computer issues related to software (e.g., downloading appropriate plug-ins, installing programs).
h. My ability to use technology to help students build new knowledge and skills.
i. My ability to anticipate likely student misconceptions within a particular topic
j. My ability to determine a particular strategy best suited to teach a specific concept.
k. My ability to use technology to predict students' skill/understanding of a particular topic.
l. My ability to implement various technology to support different teaching methods (i.e., inquiry based instruction, direct instruction, cooperative learning, etc.).
m. My ability to plan the sequence of concepts taught within my class.
n. My ability to moderate web-based student interactivity on discussion boards, blogs, social networking sites, learning management systems, etc.
o. My ability to use technological representations (i.e. multimedia, visual demonstrations, etc) to demonstrate specific concepts in my content area.
p. My ability to encourage interactivity among students using technology including Web 2.0 tools (i.e., blogs, social networking sites, learning management systems, etc.).
q. My ability to assist students with troubleshooting technical problems with computers.
r. My ability to adjust teaching methodology based on student performance/feedback.

s. My ability to comfortably produce lesson plans with an appreciation for the topic.
t. My ability to implement district curriculum in a technology-rich environment.
u. My ability to assist students in noticing connections between various concepts in a curriculum.
v. My ability to use various web-based courseware/applications to support instruction.
w. My ability to use technology to create effective representations of content that depart from textbook knowledge.
x. My ability to meet the overall demands of teaching effectively in the 21st century.

APPENDIX B

TPACK RUBRIC

Directions

Thank you for agreeing to help me score these lesson plans. You have been given lesson plans to score and each of those lesson plans was assigned a participant ID. You will score each lesson plan using a rubric created in SurveyMonkey for ease of data collection.

1. Read the TPACK primer to familiarize yourself with the general framework and each of the seven constructs. Please refer back to the primer as needed while you are scoring the lesson plans.
2. Click the SurveyMonkey link.
3. Enter the participant ID associated with the lesson plan you intend to score.
4. Complete each of the items by selecting the appropriate choice or choices or by entering text.
5. Click Submit.
6. Complete step 2 through 5 until you have scored all the assigned lesson plans.

TPACK primer/definitions

Please read the TPACK explanation of the seven components of the TPACK framework here.

TPACK Rubric (Akcaoglu, Kereluik, & Casperson, 2011)

Construct	Item	Scale
Content	• Provides Clear Lesson Objectives • Evidence of content knowledge	Poor to Excellent
Pedagogy	• Assessments are aligned with the objectives and instructional strategies • Lesson organizes and manages student behavior – Explains sequence of events and procedures for students • Content is meaningful and relevant to	Poor to Excellent

	students.	
Technology	• Lesson plan incorporates technology • Provides rationale for technology choice • Demonstrates understanding of technology	Poor to Excellent
Pedagogical Content Knowledge	• Selects effective teaching strategies appropriate to subject domain to guide student thinking and learning • Demonstrates awareness of possible student misconceptions • Presents appropriate strategies for developing understanding of the subject content	Poor to Excellent
Technological Pedagogical Knowledge	• Chooses technologies enhancing approaches (teacher centered approaches) --Uses technology to present material • Chooses technologies enhancing student learning (student centered approaches) --Students use technology to explore content and achieve learning goals • Provides clear rationale for technology choice to deliver instruction	Poor to Excellent
Technological Content Knowledge	• Chooses appropriate technologies for subject domain (mathematics, science) • Link between technology and content is obvious or explicit	Poor to Excellent
Technological Pedagogical Content Knowledge	• Appropriately uses content, pedagogy, and technology strategies in concert • Technology enhances content objectives and instructional strategies and instructional strategies	Poor to Excellent

APPENDIX C

INTERVIEW SCRIPT

Introduction:
We're talking to graduate students in Teachers College about their experiences with teaching with technology and learning to teach with technology.

Just so you know, your answers and our conversation will be totally confidential. We won't be reporting names or any other identifiers with our findings.

Interview Questions:

1. What grade and subject do you teach?

2. How many years of teaching experience do you have?

3. Can you tell me what a typical lesson looks like in your classroom (50-75 mins. Lesson)?
    a. What influenced you on how you set up or plan a lesson (class, book, article, PD, observation, experience)?

4. What are some of the most effective teaching methods (general) that you use?
    a. Where did you learn about those teaching methods?
    b. How did you discover that they were effective?

5. What were some of the influences or resources that helped you gain your knowledge in your specific content/subject area?
    a. How were you drawn to this content/subject area?

6. Outside of teaching, do you use technology in your personal and work life?
    a. How did you learn to use those technologies?
    b. Do you enjoy using technology in your personal and work life?

7. What are your opinions about the use of technology in teaching?
    a. Can you tell me a little bit more about that?
    b. Can you tell me how you developed that thought/opinion?

8. Describe an early instance where you saw an effective use of technology in teaching.
    a. What did you think after you saw that use of technology?

9. Describe the first time you taught with technology.
    a. How did you decide to use technology in your teaching?
    b. How did you decide on that specific technology to try out first?
    c. How did you choose that specific lesson to integrate technology?

10. What has influenced the use of technology in your teaching?
    a. Can you give me some examples?

APPENDIX D

IRB APPROVAL

Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Robert Atkinson BYENG
From:	Mark Roosa, Chair Soc Beh IRB
Date:	09/14/2012
Committee Action:	**Exemption Granted**
IRB Action Date:	09/14/2012
IRB Protocol #:	1208008189
Study Title:	Technological Pedagogical Content Knowledge in Graduate Teacher Education

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.