An Investigation of the Relationship between Self-Efficacy Beliefs about Technology Integration and Technological Pedagogical Content Knowledge (TPACK) among Preservice Teachers

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Abstract

This exploratory study investigated the relationship between measures of Technological Pedagogical Content Knowledge (TPACK) and the self-efficacy beliefs of preservice teachers about technology integration. Within a single-group, pretest–posttest design, a correlational analysis identified several knowledge domains in the TPACK model that the researcher found to have a significant and positive correlation with self-efficacy beliefs about technology integration. A multiple regression analysis of pretest and posttest data indicated a change over time in the predictive relationship between the measures of knowledge in TPACK domains and self-efficacy beliefs. Findings from the study illustrate the changing nature of the complex relationship between knowledge and self-efficacy beliefs and highlight the potential areas of knowledge in TPACK domains that influence preservice teachers' beliefs about technology integration. (Keywords: Self-efficacy, Technological Pedagogical Content Knowledge, technology integration, preservice teachers)

The challenge of preparing future educators who use technology in an effective, engaging, and innovative manner has led to a wide variety of approaches to using technology in teacher preparation programs as well as many ways to evaluate how these efforts lead to improved technology integration in K–12 classrooms. Whether teacher preparation programs integrate technology throughout the curriculum or use standalone courses focusing on educational uses of technology, there is a persistent challenge to understand the knowledge, beliefs, and attitudes of preservice teachers and how these factors influence future teaching practices when these students become professional educators.

The discussion of factors that influence preservice teachers' future instructional practices largely, and logically, focuses on what can be observed during a teacher preparation program. Specifically, understanding preservice teachers' knowledge, attitudes, and beliefs about educational technology provides insight into how they are likely to use technology in a classroom environment in the future. Pajares (1992) discusses the relationship and distinctions between knowledge and beliefs and the influence these might have on the teaching practices of future educators. Among his many assertions concerning beliefs, Pajares states that "knowledge and beliefs are inextricably intertwined" and that "beliefs are instrumental in defining tasks and selecting the cognitive tools with which to interpret, plan, and make decisions regarding such tasks" (1992, p. 325). Knowledge of teaching and learning, as well as evolving attitudes and beliefs, are among the attributes of individual preservice teachers that inform and influence the decisions they will make and behaviors they will exhibit as professional educators.

When considering how to design teacher preparation experiences that will develop skilled and knowledgeable educators who use technology to create engaging and effective classroom environments, researchers have found both knowledge and beliefs to be useful in understanding the processes at work. They have also found that the beliefs and attitudes of both inservice and preservice teachers concerning computers and technology explain and predict classroom technology use (Albion, 1999; Anderson & Maninger, 2007; Bull, 2009; Lee, Cerreto, & Lee, 2009; Marcinkiewicz, 1994; Vannatta & Fordham, 2004). Similar measures of beliefs and attitudes have also been used as outcome measures indicating the effectiveness of teacher preparation for technology integration (Abbitt & Klett, 2007; Hansen, Donovan, & Fitts, 2009; Heo, 2009; Wang, Ertmer, & Newby, 2004; Watson, 2006). Beliefs and attitudes, however, fall short of explaining all that may promote effective technology integration in teaching and learning.

The ever-changing nature of technology has made the knowledge base for technology a moving target in terms of its relationship with teachers' ability to successfully integrate technology into classroom practices. The Technological Pedagogical Content Knowledge (TPACK) framework described by Mishra and Koehler (2006) has been gaining popularity in educational technology research as a model for the knowledge that supports technology integration. Described as a "framework for teacher knowledge" (Mishra & Koehler, 2006), the TPACK framework has been used in the context of multiple teacher preparation and professional development programs to investigate and understand specific learning activities and environments (Archambault & Crippen, 2009; Doering, Scharber, & Miller, 2009; Graham et al., 2009; Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2005; Mishra, Koehler, Hershey, & Peruski, 2002; Shin et al., 2009). Teacher preparation efforts that focus solely on developing knowledge, however, also face the challenge of addressing the complete picture of how preservice teachers become practicing teachers who use technology in creative and effective practice.

Ertmer and Ottenbreit-Leftwich (2010) described the influence of self-efficacy beliefs, knowledge, pedagogical beliefs, and cultural contexts on technology integration and specifically address the connection between knowledge and self-efficacy beliefs by stating that "although knowledge of technology is necessary, it is not enough if teachers do not also feel confident using that knowledge to facilitate student learning" (Ertmer & Ottenbreit-Leftwich, 2010, p. 261). Measures of both knowledge and beliefs separately can yield unique and informative insights into the preparation of teachers to use technology to create engaging and effective classroom environments. However, examining the relationship between knowledge about technology integration and self-efficacy beliefs can provide a unique connection between these two areas of research. As such, it was the focus of this study to explore the relationship between preservice teachers' perceived knowledge and self-efficacy beliefs regarding their ability to successfully use technology in the classroom. To this end, the following questions guided this research study:

1. How are self-efficacy beliefs about technology integration related to the components of the TPACK model?
2. To what extent are measures of perceived knowledge in the TPACK domains able to predict self-efficacy beliefs about technology integration?
3. How does the predictive relationship among perceived knowledge in the TPACK domains and self-efficacy beliefs change over time?

Review of Relevant Literature

The development of this study was largely informed by two primary concepts that have been used to investigate teacher preparation experiences that seek to improve technology integration by preservice teachers. The TPACK framework (Mishra & Koehler, 2006) provided the conceptual model for teacher knowledge relating to technology integration. Bandura's (1997) theory of self-efficacy provided a basis for understanding the influence of preservice teachers' beliefs about their ability to successfully integrate technology on their future teaching practices. The following is a discussion of these two concepts as they relate to this study.

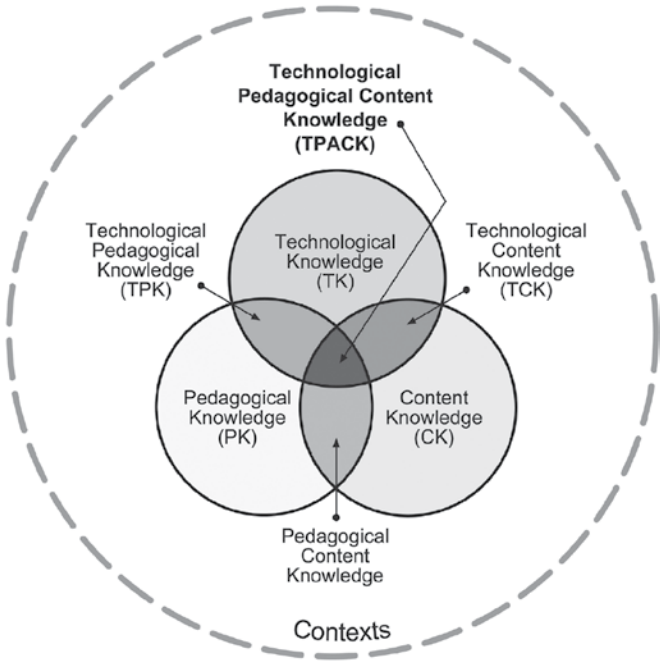

Figure 1. Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006)

The TPACK Framework

Based on Shulman's (1986) theory of Pedagogical Content Knowledge (PCK), the TPACK framework is a conceptual model for the knowledge that supports effective technology integration into classroom teaching practices (Mishra & Koehler, 2006). Illustrated in Figure 1, the TPACK framework is a representation of the complex interactions among the types of essential knowledge for successful teaching with technology.

As with Shulman's (1986) concept of PCK, the TPACK framework articulates content knowledge (CK) and pedagogical knowledge (PK) as primary areas of teacher knowledge as well as a PCK domain that illustrates the knowledge of pedagogy that is particularly suited to a specific content area. By extending the PCK model to include technological knowledge (TK) as a third major area of knowledge, the TPACK framework illustrates three additional interactions among these knowledge domains: technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK) (Koehler & Mishra, 2005; Mishra & Koehler, 2006). Table 1 (p. 136) includes descriptions of the three primary domains of knowledge (TK, PK, CK) as well as the four blended domains (PCK, TCK, TPK, TPCK) that the TPACK framework illustrates. In an effort to maintain clarity, this paper identifies the blended knowledge domain of technological pedagogical content knowledge using the acronym TPCK to distinguish the individual construct from the title of the knowledge model identified using the acronym TPACK.

The TPACK framework emerged from a series of design experiments that investigated the ways that teachers use knowledge to develop uses of technology in teaching and learning. In 2004, Koehler, Mishra, Hershey, and Peruski described the experiences of a faculty member working with a design team to develop an online course. The authors suggest that this approach was effective due to the ongoing discussion of the

Table 1. Brief Descriptions of the Knowledge Domain Represented in the TPACK Framework (Koehler & Mishra, 2007; Mishra & Koehler, 2006)

Knowledge Domain	Description
Pedagogical (PK)	Knowledge of nature of teaching and learning, including teaching methods, classroom management, instructional planning, assessment of student learning, etc.
Content (CK)	Knowledge of the subject matter to be taught (e.g., earth science, mathematics, language arts, etc.).
Technology (TK)	Continually changing and evolving knowledge base that includes knowledge of technology for information processing, communications, and problem solving and focuses on the productive applications of technology in both work and daily life.
Pedagogical Content (PCK)	Knowledge of the pedagogies, teaching practices, and planning processes that are applicable and appropriate to teaching a given subject matter.
Technological Content (TCK)	Knowledge of the relationship between subject matter and technology including knowledge of technology that has influenced and is used in exploring a given content discipline.
Technological Pedagogical (TPK)	Knowledge of the influence of technology on teaching and learning as well as the affordances and constraints of technology with regard to pedagogical designs and strategies.
Technological Pedagogical Content (TPCK)	Knowledge of the complex interaction among the principle knowledge domains (content, pedagogy, technology).

affordances and constraints between the technology systems, pedagogical design, and content of the course. A later study of a similar design-team context analyzed observational notes, e-mail between group members, artifacts created by the groups, and self-reporting surveys that the researchers organized into discourse episodes (Koehler, Mishra, & Yahya, 2007). They categorized and coded these discourse episodes according to the topics of content, pedagogy, and technology. The analysis of these discourse episodes revealed a trend that began with discussions of technology, pedagogy, and content independently and moved toward more complex discussions of the interactions among these concepts.

Although the PCK model has been adapted to include a representation of technology in other ways (Hughes, 2005; Keating & Evans, 2001; Margerum-Leys & Marx, 2002; Niess, 2005), the TPACK framework provides a unique emphasis on the intersections and interaction among the three primary domains as well as operational definitions of the seven constructs. The interaction of all three knowledge domains is where the model articulates the integrated knowledge that a teacher must possess to integrate technology that is most successful. This representation of the domains of teacher knowledge and the complex relationships among them provides a basis for understanding teacher knowledge that supports successful technology integration into classroom learning environments.

Self-Efficacy Beliefs about Technology Integration

As a general construct, self-efficacy is a perception about one's abilities within a given domain. Bandura (1997) described perceived self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). He further explains that self-efficacy beliefs influence many aspects of behavior, including the choice of a course of action, the amount and duration of effort put forth, and the emotional response to the success of an endeavor (Bandura, 1997, p. 3). Self-efficacy theory suggests that the beliefs concerning one's ability to affect a desired outcome influences both thought and action. In general, it is expected that higher self-efficacy beliefs will function as a positive support for action, whereas lower self-efficacy beliefs can have hindering effects on the decision to proceed with a particular course of action.

Although self-efficacy beliefs will influence decisions and behaviors, these self-efficacy beliefs are influenced by other characteristics and prior experience within a particular domain. Bandura (1997) described the four primary influences on self-efficacy beliefs as (a) enactive mastery experiences, (b) vicarious experiences, (c) social influences, and (d) physiological and affective states. Among these four influences, mastery experiences were suggested as having the strongest influence on self-efficacy beliefs and thus a strong influence on behavior. The influence of these experiences on self-efficacy will vary depending on whether or not success was achieved as well as the effort required to do so. Enactive mastery experiences in which a person experiences success will lead to increased self-efficacy, provided that these experiences are in an authentic environment and the task requires "overcoming obstacles through perseverant effort" (Bandura, 1997, p. 80). However, success that comes without effort is not likely to have a positive influence on self-efficacy. Further, failures in an authentic environment are likely to decrease self-efficacy beliefs. Concerning teachers specifically, Bandura suggests that pedagogical decisions that teachers make are influenced by self-efficacy beliefs regarding their own capabilities.

With regard to technology in teaching and learning, multiple domains of self-efficacy beliefs may play a role in a teacher's thoughts and actions regarding technology in the classroom. Albion (1999) argued that instructional strategies such as problem-based learning (PBL) influence self-efficacy beliefs and can serve as a way to improve a teacher's ability to effectively use technology in classroom teaching practices. In a later study, Albion (2001) found that the amount of time spent using a computer was positively correlated with self-efficacy beliefs regarding computer use. Albion suggested that coursework in teacher education programs "should be structured and taught using approaches which build the confidence of students in their capacity for effective computer use" (p. 345) as a means for supporting effective technology use in their future profession.

In a study of preservice teachers enrolled in an introductory educational technology course, Wang, Ertmer, and Newby (2004) focused specifically on self-efficacy beliefs regarding technology integration as measured by the Computer Technology Integration Survey (CTIS). Wang et al. (2004) studied the influence of vicarious learning experiences and goal setting on the self-efficacy beliefs for technology integration of 408 preservice teachers. Participants in the study were randomly assigned to either a control group or experimental conditions that included either watching videos from K–12 classrooms (vicarious learning experiences) or evaluating a learning activity based on a specific goal (goal setting). The study found that both goal setting and vicarious learning experiences had a significant and positive influence on self-efficacy beliefs toward technology integration as measured by the CTIS. The increase in self-efficacy beliefs was largest for the group that experienced both the vicarious learning experience and goal-setting conditions.

Researchers have suggested that self-efficacy beliefs relating to computer use as well as technology integration into teaching influence a teacher's ability to create learning environments that use technology in meaningful ways. Bandura acknowledged, however, that these beliefs "partly determine how they structure academic activities in their classroom" (1997, p. 240). As such, beliefs about one's abilities to use technology in a classroom environment are only part of what should be considered when preparing preservice teachers for effective and meaningful technology integration in the teaching and learning environments.

TPACK and Self-Efficacy

The TPACK framework suggests that integrated knowledge of technology, pedagogy, and content is an essential condition to effective and innovative classroom teaching using technology. Further, self-efficacy beliefs regarding abilities to integrate technology into teaching are also considered a factor influencing decisions a teacher would make about the use of technology in the classroom. Bandura's theory of self-efficacy would suggest that increasing teacher knowledge would lead to increased self-efficacy beliefs and, potentially, to an increase in technology use in the classroom as well as an increased likelihood that this technology use will be based on knowledge of pedagogy and content. Sahin, Akturk, and Schmidt (2009) investigated the relationship between preservice teachers' perceived knowledge in TPACK domains and their beliefs about their abilities to teach in a classroom (vocational self-efficacy beliefs). The data analysis used students' grades from technology, pedagogy, and content courses as a measure of knowledge in TPACK domains and responses to a survey as a measure of vocational self-efficacy. The study found significant differences in vocational self-efficacy beliefs among groups of students with differing levels of knowledge in technology, pedagogy, and content knowledge. Although Sahin, Akturk, and Schmidt identified a possible relationship between TPACK and self-efficacy beliefs toward teaching, the study also revealed that the complex nature of this relationship requires further study. Understanding the nature of the relationship between the types of knowledge represented by the TPACK framework and preservice teachers' self-efficacy beliefs about technology integration will provide insight relevant to the development of teacher preparation experiences that could ultimately lead to more successful technology integration by preservice teachers.

Methodology

Overview of Methodology

This study used a single-group, pretest–posttest design to evaluate the relationship between self-efficacy beliefs toward technology integration (SE-TI) and perceived knowledge in TPACK domains. Using data collected at the beginning and end of a course focusing on technology integration into teaching, the researcher conducted the analysis of the relationship of SE-TI and TPACK using data from both the pretest and posttest to identify possible changes in the relationship over time.

Research Context and Sample

The participants in the study included 45 preservice teachers, comprising approximately 90% of a single cohort group enrolled in a teacher preparation program in early childhood education (ECE). At the time of the study, the cohort group was enrolled in a one-credit course focusing on technology integration into teaching that met each week for 50 minutes. Course activities during the 16-week course were designed to improve preservice teachers' technology skills and demonstrate technology-enhanced approaches to teaching. Forty-eight out of the 50 members of the cohort group were female, so to maintain the anonymity of the survey instrument, gender information was not collected with the survey. The mean age for the sample was 21.3 years old, and 96% of respondents were between 21 and 22 years old at the beginning of the course. The members of the cohort group, and thus the sample, were in their final semester of coursework prior to a 16-week teaching internship and completion of the ECE program.

Survey Instruments

To measure knowledge in the TPACK domains and self-efficacy beliefs about technology integration, the researcher administered two established research instruments via a Web-based survey system.

The researcher measured perceived knowledge in the TPACK domains using the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009). This survey is a 47-item Likert scale survey with items that included 10 subscale measures for each TPACK domain, including 4 subscales for different areas of content knowledge (literacy, social studies, mathematics, and science). Participants rated their agreement with each item on a 5-point Likert scale (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree). The

Table 2. Cronbach's Alpha Values for Survey Subscales on Pretest and Posttest (N=45)

Scale	# survey items	Pretest	Posttest
Technological Knowledge (TK)	7	.87	.92
Social Studies Content Knowledge (SS-CK)	3	.86	.90
Mathematics Content Knowledge (M-CK)	3	.94	.94
Science Content Knowledge (S-CK)	3	.87	.94
Literacy Content Knowledge (L-CK)	3	.91	.95
Pedagogical Knowledge (PK)	7	.90	.91
Pedagogical Content Knowledge (PCK)	4	.78	.88
Technological Pedagogical Knowledge (TPK)	5	.90	.93
Technological Content Knowledge (TCK)	4	.82	.93
Technological Pedagogical Content Knowledge (TPCK)	8	.95	.96
Self-Efficacy for Technology Integration	16	.95	.96

Table 3. Descriptive Statistics for Subscales on Pretest and Posttest (N=45)

Scale	Posttest		Posttest		Mean Diff.
	Mean	SD	Mean	SD	
Technological Knowledge (TK)	3.40	.66	3.42	.82	.02
Social Studies Content Knowledge (SS-CK)	3.44	.74	3.76	.76	.32
Mathematics Content Knowledge (M-CK)	3.61	.95	3.81	.81	.20
Science Content Knowledge (S-CK)	3.23	.81	3.51	.79	.28
Literacy Content Knowledge (L-CK)	4.29	.54	4.38	.52	.09
Pedagogical Knowledge (PK)	3.97	.47	4.33	.45	.36
Pedagogical Content Knowledge (PCK)	3.48	.58	4.19	.48	.71
Technological Pedagogical Knowledge (TPK)	3.59	.75	3.89	.75	.30
Technological Content Knowledge (TCK)	2.93	.65	3.80	.77	.87
Technological Pedagogical Content Knowledge (TPCK)	3.26	.81	3.92	.64	.66
Self-Efficacy for Technology Integration (SE-TI)	3.56	.86	3.85	.68	.29

measure of TPACK domains used in this study represents participants' self-assessment of their knowledge. Schmidt et al. described the development and validation of this instrument and reported Cronbach's alpha coefficients for the subscales ranging from .75 to .92. The survey was developed specifically for use with elementary and/or early childhood education preservice teachers, so it included multiple subscales to assess perceived content knowledge in all content areas that the students would potentially be teaching in their future classrooms, including mathematics, science, social studies, and literacy.

Wang et al. (2004) developed the CTIS instrument to measure participants' self-efficacy beliefs regarding using technology in teaching. The CTIS instrument used in this study included 16 positively worded statements relating to perceived confidence in successfully integrating technology into teaching practices. Participants rate each item on a 5-point Likert scale (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree). Higher scores on the CTIS scale indicated higher perceived self-efficacy toward the integration of technology into teaching practices. During the development of the CTIS instrument, Wang et al. (2004) evaluated a 21-item version of the survey and reduced the instrument to include 16 items. Internal consistency of the instrument was evaluated using a Cronbach's alpha coefficient with values of .94 and .96 calculated for the presurvey and postsurvey, respectively (Wang et al., 2004).

The researcher administered the TPACK and CTIS instruments as a combined instrument, though items were presented in contiguous sections of the online form. To maintain readability and a reasonable page length when viewing the survey, items from the TPACK instrument were presented on the first two pages of the online survey, whereas items from the CTIS instrument were presented on the third page. Measures of internal consistency of the subscales from the combined instrument were similar to those previously reported for each instrument. As shown in Table 2, Cronbach's alpha values for the TPACK subscales ranged from .78 to .95 on the pretest and from .88 to .96 on the posttest. The Cronbach's alpha value for the CTIS subscale was .95 on the pretest and .96 on the posttest.

Procedures

The researcher administered the combined TPACK/CTIS survey via an online survey system two times during the 16-week semester that students were enrolled in the course on technology integration into classroom teaching. A hyperlink to the survey and description of the study were available for the first week of the semester on the course website and were also e-mailed directly to the students and distributed on paper handouts to encourage participation. Participation in the study was voluntary, and the survey was anonymous, although it included a nonidentifiable unique code that the students would enter into the survey to allow for matching the pretest and posttest responses anonymously. The Institutional Review Board at the institution where the research was conducted reviewed and approved all procedures.

The combined TPACK/CTIS survey included the seven subscale measures from the TPACK instrument and one subscale measure from the CTIS instrument. For each subscale, the researcher calculated a mean value of all subscale items for each participant. Scoring of the survey items was consistent with the procedures described by the relevant literature for both the original TPACK survey (Schmidt et al., 2009) and the CTIS (Wang et al., 2004). Table 3 presents the mean ratings of perceived knowledge in TPACK domains and self-efficacy beliefs for the pretest

Table 4. Bivariate Correlation Coefficients for TPACK Subscales and Self-Efficacy Beliefs about Technology Integration (N=45)

	Pretest		Posttest	
	r	r^2	*r*	r^2
TK	.599**	.359	.763**	.582
SS-CK	.041		.080	
M-CK	.011		.207	
S-CK	.033		.251	
L-CK	-.127		.228	
PK	.337*	.114	.359*	.129
PCK	.071		.488**	.238
TPK	.644**	.412	.837**	.701
TCK	.620**	.384	.761**	.579
TPCK	.853**	.728	.813**	.656

*$p < .05$

**$p < .01$

Table 5. Regression of Self-Efficacy Beliefs toward Technology Integration on Perceived Knowledge in TPACK Domains (Pretest)

Variable	B	SE		*t*	*sr*	95% CI
TK	.22	.28	.21	2.42	.183	[.04, .41]
TPCK	.62	.07	.74	8.38	.633	[.47, .77]

Note: $R^2 = .760$, Adjusted $R^2 = .749$, $p < .01$

Table 6. Regression of Self-Efficacy Beliefs toward Technology Integration on Perceived Knowledge in TPACK Domains (Posttest)

Variable	B	SE		*t*	*sr*	95% CI
TK	.37	.07	.44	5.31	.35	[.23, 51]
PK	-.24	.14	-.16	-1.75	-.11	[-.51, .04]
PCK	.35	.14	.25	.25	.17	[.08, .62]
TPK	.47	.47	.09	5.30	.34	[.29, .65]

Note: $R^2 = .831$, adjusted $R^2 = .814$, $p < .01$

and posttest. At the beginning of the semester, ratings of perceived knowledge and self-efficacy beliefs, except for TCK, were above the midpoint of the rating scale. Ratings of both knowledge and self-efficacy beliefs increased during the semester. The largest increase occurred in ratings of TCK, whereas the smallest increase occurred in TK.

Results

This study focused on the relationship of perceived knowledge in the TPACK domains with self-efficacy beliefs about technology integration. As such, the analysis of data first evaluated the bivariate relationships between self-efficacy beliefs (SE-TI) and the TPACK subscales using a Pearson Product-Moment correlation. The researcher calculated a correlation coefficient between the subscale score measuring self-efficacy about technology integration (SE-TI) and each of the TPACK subscales for the pretest and posttest data. The bivariate relationships among the variables measured on the pretest, as Table 4 shows, revealed moderately strong and significant positive correlations between SE-TI and the subscale measurements of perceived TPCK ($r = .853$, $p < .01$), TPK ($r = .644$, $p < .01$), TCK (r = .620, $p < .01$), and TK ($r = .599$, $p < .01$). A statistically significant, although weaker, correlation was also found between self-efficacy beliefs and PK ($r = .337$, $p < .05$).

An analysis of bivariate relationships among the same variables using posttest data revealed stronger positive correlations between self-efficacy beliefs and the same TPACK domains (TPCK, TPK, TCK, TK, and PK). One additional correlation was found in the posttest data that was not significant in the pretest data between self-efficacy beliefs and perceived PCK ($r = .488$, $p < .01$).

Analysis of Predictive Relationship between TPACK and Self-Efficacy Beliefs

Following the analysis of bivariate relationships, the researcher conducted a multiple regression analysis to determine the degree to which ratings of perceived knowledge in TPACK domains may have contributed to SE-TI. He used a backward selection technique that initially included all TPACK variables that had a significant relationship with self-efficacy beliefs and subsequently removed those that were not significant in the model.

As Table 5 shows, the analysis of the pretest data indicated that the subscale measurements of perceived TK and TPCK were significant predictors and accounted for approximately 76% of the variance in SE-TI. As mean ratings of TK increased by 1, mean values for SE-TI increased by .22. Perceptions of TK uniquely accounted for approximately 18% of the variance in SE-TI. As mean values for TPCK increased by 1, mean values for SE-TI increased by .62. Perceived TPCK uniquely accounted for approximately 63% of the variance in SE-TI.

The analysis of posttest data collected at the end of the academic term indicated that TK, PK, PCK, and TPK were significant predictors and accounted for approximately 83% of the variance in self-efficacy beliefs. As Table 6 shows, increases in the TK, PCK, and TPK resulted in increases in self-efficacy ratings. PK, however, had a negative influence on self-efficacy beliefs in the model. As mean values for PK increased by 1, mean values for self-efficacy beliefs decreased by .24.

Discussion

The goal of this study was to explore the relationship between preservice teachers' perceived knowledge, as represented by the TPACK framework, and self-efficacy beliefs about their ability to successfully use technology in the classroom. The data analysis suggests that knowledge in the TPACK domains may be predictive of self-efficacy beliefs about technology integration and that this relationship is dynamic and changing within the context of one semester of a teacher preparation program.

Limitations of the Study

In examining the results of this exploratory study, some characteristics of the sample, context, and measurements are notable in the discussion of the results. Limitations to this study arise from the focus on a cohort group of preservice teachers enrolled in an early childhood education program. The sample included 45 of the 50 members of the cohort group. However, the cohort group is predominantly female and included few students of diverse backgrounds. Further, the researcher collected the data during a single 16-week academic term. Although these results may be representative of this cohort group, the ability to generalize these results to more diverse student populations, over longer time periods, or other contexts may be limited.

An additional limitation of this study is the focus on participants' perceptions of knowledge in the TPACK domains and self-efficacy beliefs. As such, the subscale measurements represent perceptions of knowledge and beliefs rather than evidence of demonstrated knowledge and ability. The extent to which these instruments can represent preservice teachers' actual knowledge is limited by the respondents' ability to conduct an accurate self-appraisal of their own knowledge and beliefs.

Relationship of Individual TPACK Constructs and Self-Efficacy Beliefs

The finding that perceived knowledge in multiple TPACK domains is positive suggests that efforts to improve teacher knowledge in the TPACK domains may result in increased self-efficacy beliefs. These findings are consistent with Bandura's (1997) description of how knowledge and self-efficacy function and prior findings regarding TPACK and vocational self-efficacy beliefs (Sahin, Akturk, & Schmidt, 2009). The bivariate relationships between self-efficacy and individual TPACK domains, however, revealed that not all of the TPACK domains had a similar relationship with self-efficacy beliefs for technology integration. Perceptions of CK in math, science, social studies, and literacy had no significant relationship with self-efficacy beliefs about technology integration, whereas the relationships with PK and PCK were found to be weak. Within the sample, self-efficacy beliefs about technology integration are more strongly related to the specific knowledge domains where technology is blended with pedagogy and content knowledge (TPK, TCK, TPCK) than they are to the general knowledge about pedagogy (PK) or content-area knowledge (CK). As such, these findings suggest that specific knowledge of the intersections between knowledge of technology and the other two knowledge domains supports higher self-efficacy beliefs about technology integration. This finding supports both the use of the TPACK framework as a viable model for the knowledge base that supports technology integration as well as the idea, as Ertmer and Ottenbeit-Leftwich (2010) assert, that knowledge and self-efficacy beliefs, pedagogical beliefs, and cultural contexts are among the factors that influence technology integration.

A Changing Relationship between Self-Efficacy and TPACK

Prior research suggests that self-efficacy beliefs influence how likely a teacher is to use technology in the classroom (Albion, 1999, 2001; Bull, 2009; Kellenberger, 1996; Marcinkiewicz, 1994; Wang et al., 2004). An understanding of how these beliefs are influenced by perceived knowledge of pedagogy, content, and technology is essential when developing specific strategies for supporting meaningful learning about technology in the classroom during a teacher preparation program and, ultimately, successful technology integration in the future. Within the sample studied, the relationship among perceived knowledge and self-efficacy beliefs about technology integration was found to change over time. From the data collected at the beginning of the academic term, only two independent variables (TK and TPCK) were found to be significant predictors of self-efficacy beliefs ($R^2 = .76$). At the end of the academic term, however, a slightly stronger predictive model was found in which TK, PK, PCK, and TPK were significant predictors of self-efficacy beliefs ($R^2 = .83$). In comparing the regression models from the beginning and end of the semester, TK was the only knowledge domain found to be a significant predictor at both times. Also, the analysis identified an unexpected relationship in the posttest model in which PK was found to have an inverse predictive relationship with self-efficacy beliefs toward technology integration.

In considering the possible explanations for the change in the predictive relationship of perceived knowledge in TPACK domains and self-efficacy beliefs, it is important to reflect on the context in which the study was conducted. The participants comprised a single cohort group for whom coursework was largely the same for all members. Also, participants were enrolled in a course focused specifically on technology integration into classroom teaching practices during the academic term in which the study was conducted. Although it is not possible to attribute the change in the relationship of perceived knowledge or self-efficacy beliefs to any specific course or activity, it is reasonable to acknowledge that participants in this study were engaged in developing and refining their personal instructional strategies for technology integration into their future classrooms. As such, the findings of this study are similar to those of prior TPACK research that identified a trend toward more complex thinking about the relationship of technology to content and pedagogy over time (Koehler & Mishra, 2005; Koehler, Mishra, & Yahya, 2007).

Within this changing relationship, the nature of the predictive relationship of TK with self-efficacy beliefs is an additional finding of interest. The relative influence of this knowledge domain on self-efficacy beliefs increased over time, whereas the mean ratings of perceived

TK remained relatively unchanged between the pretest ($M = 3.40$, $SD = .66$) and posttest ($M = 3.42$, $SD = .82$). However, as perceptions of PK increased, the influence of TK on self-efficacy beliefs also increased. This suggests that even when perceived knowledge in this domain is stable over time, changes in other knowledge domains might increase the impact of TK on self-efficacy beliefs. This further suggests that efforts to increase technology integration by teaching technology skills alone may be insufficient to increase the self-efficacy beliefs of preservice teachers about technology integration. Additional support from the other knowledge domains is necessary to increase self-efficacy beliefs about technology integration. This changing relationship may indicate that, as preservice teachers learn more about how technology relates to teaching and learning, they perceive that knowledge about technology is more important to their ability to successfully integrate technology in the classroom.

In other study results, the researcher observed positive changes in all TPACK and self-efficacy subscale measures between the pretest and posttest measurements. At the beginning of the study, the perceived knowledge in the TPCK domain was found to be a significant predictor of self-efficacy beliefs. In the posttest, however, TPCK was no longer a significant predictor, whereas PK, PCK, and TPK were significant in the regression model. These results suggest that, within this cohort group of preservice teachers, the influence of knowledge about teaching practices (PK, PCK, TPK) on self-efficacy beliefs about technology integration increased over time. It is notable, however, that PK was found to have a negative influence on self-efficacy beliefs in the posttest regression model while having a positive bivariate relationship between the two variables. Within this cohort group, respondents with a higher degree of perceived PK were likely to have lower self-efficacy beliefs toward technology integration. Although this effect may be small, this result appears to be contrary to the theory that knowledge within a discipline increases self-efficacy beliefs. This result may be evidence of the increasingly complex thinking about the role of technology in teaching. However, it is also possible that this effect is the result of a mediating factor that is unaccounted for in this model. Further research is warranted to investigate this relationship in greater detail and determine whether a causal relationship exists. Given the limitations inherent in the sample, time period, and measurement instruments, it is unclear how the influence of PK might further change as the students complete a teaching internship and transition from preservice to inservice teachers.

This changing relationship has implications when considering approaches to teaching educational technology in a teacher preparation program. As preservice teachers develop a more complex view of the role of technology in education, it follows that their needs for supporting technology skills evolve as well, and they are better able to discern what technology skills are relevant to their discipline and likely to work well in their future classrooms. An approach that provides multiple opportunities to develop technology skills throughout their teacher preparation program may provide the necessary scaffolds to develop a rich knowledge base and self-efficacy beliefs about technology integration. Further, the increasing influence of the knowledge domains that include PK supports the application of TPACK as a way to influence teachers' beliefs about technology integration by emphasizing the interaction and interdependencies among foundational knowledge in pedagogy, content, and technology. As such, providing technology integration experiences at multiple points throughout a teacher preparation program as knowledge of technology, pedagogy, and content is developing may ultimately lead to a more complex and deeper understanding of the interaction among these types of knowledge as well as increased beliefs in candidates' abilities to effectively use technology to improve teaching and learning.

Suggestions for Further Research

Research on how teachers are prepared to use technology in teaching and learning will undoubtedly face the ongoing challenge of an ever-changing technological landscape as well as a wide variety of pre-existing technology knowledge and skills of incoming students seeking to become professional educators. Future research in this area will benefit from the flexibility of the TPACK framework as a model for teacher knowledge that can accommodate this ongoing change. In seeking to understand how knowledge leads to action, however, a balanced approach that incorporates relevant measures of attitudes and beliefs, as well as performance-based measures, will reveal a more complete picture of the role of technology in preservice teacher preparation. Schmidt et al. (2009) described an ongoing research agenda to determine the relationship between the self-reported measures of TPACK constructs and other performance-based measures. Future research will benefit greatly from addressing this correlation and more clearly understanding the degree to which self-reporting measures are able to predict classroom practices.

Conclusions

It is reasonable to expect that both knowledge and beliefs about one's abilities are likely to influence the success of preservice teachers as they begin their careers as educators. The TPACK framework provides a valuable structure for teacher preparation and the ways that technology creates new dynamics in the teaching and learning process. Preservice teachers' beliefs about their ability to use this knowledge in a classroom environment provide a measure that can assist in assessing the success of teacher preparation for technology integration. In exploring the complex interplay between knowledge and self-efficacy beliefs, it is possible to better use these distinct constructs as both formative and summative measures for revealing the impact of teacher preparation experience on factors that lead to preservice teachers' effective technology integration. This study has served to demonstrate the nature of this relationship in a specific context as a dynamic and evolving connection between preservice teachers' knowledge and self-efficacy beliefs about technology integration. With the support of ongoing research, the usefulness of the TPACK framework may be extended to provide a model for a relevant, rich, complex, and flexible knowledge base capable of enhancing self-efficacy beliefs for technology integration in the classroom.

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