JRTE | Vol. 46, No. 2, pp. 149–172 | ©2013 ISTE | iste.org/jrte

The Use of Confidence Intervals as a Meta-Analytic Lens to Summarize the Effects of Teacher Education Technology Courses on Preservice Teacher TPACK

Jamaal R. Young
Jemimah L. Young
Christina Hamilton
University of North Texas

Abstract

The validity and reliability of the Technological Pedagogical Content Knowledge (TPACK) framework to measure the extent to which teachers can teach with technology, hinges on the ability to aggregate results across empirical studies. We synthesized mean difference effect sizes resulting from university classroom studies, which used a survey of preservice teacher knowledge of teaching with technology (TKTT) using confidence intervals (CIs).We then characterized the mean effect sizes for the influence of classroom instruction on preservice teacher TPACK by graphing CIs across studies from 2009 until 2011. The results present approximations of TPACK population parameters as well as implications for researchers and teacher educators. (Keywords: TPACK, preservice teachers, confidence intervals, literature review)

To provide adequate service to the growing populations of digital natives, it is imperative that all teachers receive effective instruction on the affordances and constraints of digital technology integration in the classroom. Most classroom teachers, however, lack effective technology integration preparation (Bracewell, Sicilia, Park, & Tung, 2007; Ertmer, 2005). Teacher preparation programs must guide preservice teachers to develop strategies, abilities, and a presence of mind that transcends modern classrooms (Niess, 2008). Analyzing the effects of university classroom instruction on preservice teacher technological, pedagogical and content knowledge (TPACK) is worth considering in the redesign of preservice teacher preparation programs. The aggregation of research results adds to the construct validity and empirical relevance of TPACK, which strengthens the framework. Further, research that enhances the strength of the TPACK framework could provide theoretical guidance to teacher education programs that inform general and content-specific technology integration praxis (Graham, 2011). Summarizing the effectiveness of university instruction on preservice teacher TPACK would provide empirical evidence to support or refute current teacher-preparation technology integration instructional practices.

The TPACK framework provides a model for the integration of technology into classroom instruction, based on the idea that proper technology integration should account for the nuances present across content areas, pedagogical practices, and different technologies. Although TPACK is a new ideology, the integration of technology into teachers' pedagogy and content has been addressed in prior research. Multiple scholars have described the relationships among technology, content, and pedagogy (Keating & Evans, 2001; Niess, 2005; Pierson, 1999, 2001; Zhoa, 2003). Aside from TPACK, other terms such as *information and communication technology* (ICT; e.g., Angeli & Valanides, 2005), *technological content knowledge* (Slough & Connell, 2006), and *electronic PCK or e-PCK* (e.g., Franklin, 2004; Irving, 2006) also refer to the inclusion of technology in pedagogy and content.

The TPACK framework was conceptualized by Mishra and Koehler as a progression of the pedagogical content knowledge (PCK) framework initiated by Lee Shulman in 1986. Shulman described PCK as a teacher's ability to transform subject-matter knowledge into accessible forms that all learners could master. Shulman's PCK goes beyond knowledge of the subject matter, per se, to the dimension of subject matter knowledge for teaching, specifically (Shulman, 1986). Similarly, TPACK is more than a teacher's personal use of technology; it is the effective use of technology, as a pedagogical tool, within a teaching strategy. Mishra and Koehler (2006) affirmed that "TPACK is more than just an awareness of technology, pedagogy, and content, it is an awareness of the connections, interactions, affordances and constraints" (p. 1025).

A teacher's TPACK is identified as a composite of seven knowledge domains, as described by Mishra and Koehler (2006):

- Pedagogical knowledge (PK): knowledge of the nature of teaching and learning (e.g., teaching methods, classroom management, instructional planning, and assessment of student learning)
- Content knowledge (CK): knowledge of the subject matter to be taught (e.g., earth science, mathematics, or language arts)
- Technological knowledge (TK): knowledge of the continually changing and evolving technologies used for information processing, communications, and problem solving, focusing on the productive applications of technology in both work and daily life
- Pedagogical content knowledge (PCK): knowledge of the pedagogies, teaching practices, and planning processes that are applicable and appropriate to teaching a given subject matter
- Technological content knowledge (TCK): knowledge of the relationship between subject matter and technology, including knowledge of technology that has influenced or been used to explore a given content discipline

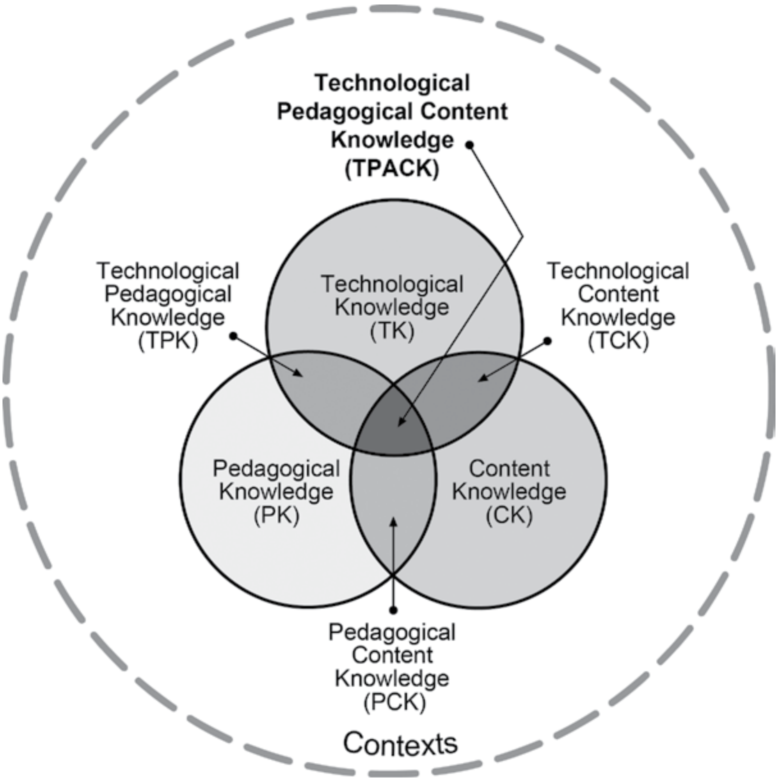

Figure 1. The technological pedagogical content knowledge framework. Adapted from "Technological pedagogical content knowledge: A framework for teacher knowledge," by Mishra and Koehler, 2006, *Teachers College Record,* p. 1025.

- Technological pedagogical knowledge (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 knowledge (TPCK): knowledge of the complex interactions among the principle knowledge domains (content, pedagogy, and technology)

As the knowledge domains suggest, the teacher must not only know a content-specific technological tool but also understand how that tool could be properly used in lessons, how to operate the tool, how to troubleshoot the tool, and how to modify the tool to fit the intended purpose. Thus, the TPACK framework provides a model for the integration of technology into classroom instruction, grounded on the idea that proper technology integration should account for the nuances present across various content areas, pedagogical practices, and technologies.

Measuring the Effectiveness of Instruction on Preservice Teacher TPACK

The TPACK instructional framework is, by design, fluid rather than rigid. Thus, both naturally and appropriately, there are many variations in the measurement instrumentations used to examine the nuances of the TPACK framework. Three major categories constitute the available TPACK preservice teacher instruments: observation, performance assessments, and self-reported surveys (Graham, Burgoyne, & Borup, 2010; Harris, Grandgenett, & Hofer, 2010; Sahin, Akturk, & Schmidt, 2009; Schmidt, Sahin, Thompson, & Seymour, 2008). Preservice teacher TPACK is also assessed through interviews and open-ended questionnaires, but the focus of this discussion is formal instrumentation that is established in the literature.

Observation Instruments

Observational measurement is an emerging trend in TPACK research. Despite its infancy, observational assessments of TPACK are promising given the authentic nature of classroom technology integration activities under investigation. To this end, researchers are developing and evaluating several observational instruments. In a survey of TPACK measurement instruments across studies from 2006 to 2010, Koehler, Shin, and Mira (2012) found that observational measurement was used in 34% of the 63 preservice teacher studies (p. 21). Based on the development and evaluation of several observational instruments and protocols the implementation of observational measures continues to grow. This growth is evident in trends towards including observational measures in more recent assessments of teacher TPACK (Agyei & Keengwe, 2012; Jang & Chen, 2010; Niess, 2011). As the theoretical and methodological development of TPACK continues to proliferate better observation instruments and procedures will materialize.

Performance Assessment Instruments

Performance assessments allow researchers to examine participant performance on authentic task. These assessments also allow researchers to evaluate artifacts to measure particular constructs. Lesson plans are an essential instructional artifact from teacher education programs as well as, a fundamental pedagogical element of most teacher education programs. Aptly, designing effective and engaging lesson plans is a fundamental element of successful teaching (Butt, 2006).

Harris, Grandgenett, and Hofer (2010) developed and validated an instrument to evaluate elements of TPACK present in teacher lesson plans. The Technology Integration Assessment Rubric (TIAR) was developed through the adaptation of the Technology Integration Assessment Instrument (TIAI). The TIAI was designed to assess general technology integration in lesson plans across seven constructs: planning for technology use, content standards, technology standards, differentiation, use of technology for learning, use of technology for teaching, and assessment (Britten & Cassady, 2005). Harris, Grandgenett and Hofer (2010) aligned the TIAI instrument to the TPK, TCK, and TPACK constructs. Since the initial development of the TIAR, several researchers have adapted and transformed the instrument to meet study specific assessment needs (Agyei & Voogt, 2011; Hofer, Gandgenett, Harris, & Swan, 2011). The TIAR is one of several lesson plan evaluation rubrics. Although other rubrics are under development (Kereluik, Casperson, & Akcaoglu, 2010), the TIAR is currently the most cited and utilized TPACK lesson plan rubric. Performance assessments of TPACK continue to evolve, but survey instruments represent the most diverse and robust instruments in the TPACK literature.

Survey Instruments

Several diverse survey instruments are currently available to measure teacher TPACK (Archambault, & Crippen, 2009; Jamieson-Proctor, Finger, Albion, 2010; Mishra & Koehler, 2005; Schmidt, Baran, Thompson, Koehler, Sahin & Erdogan, 2010; Shin, & Mishra, 2009). Despite the vast array of available survey instruments to measure TPACK, some of the aforementioned instruments were designed for use with inservice teachers. Four distinct survey instruments represent the most well researched and documented preservice teacher TPACK survey instruments (Jamieson-Proctor, Finger, & Albion, 2010; Mishra & Koehler, 2005; Sahin & Erdogan, 2010; Schmidt et al., 2009).

Jamieson-Proctor, Finger, Albion (2010) administered the TPACK Confidence survey to senior preservice teachers in association with an ICT course. The survey consisted of 25 items, and was aligned to specific course learning objectives. Mishra and Koehler (2005) designed their survey for administration in a specific faculty development course to measure participant attitudes, opinions, and learning. Because the focus of the course was learning by the design, faculty as well as graduate students participated in the course and survey. Accordingly, the questions in the survey were written specifically for this context. For example, one item read, “Our group has been considering how course pedagogy and technology influence one another” (Mishra & Koehler, 2005). The Sahin and Erdogan (2010) survey was administered to college students to address their acquaintance with different applications of TPACK. The TPACK Confidence survey addressed specific elements of TPACK as the related to Information Communication Technology (ICT). The nature of TPACK promotes the need to develop context specific instruments that parallel the theoretical foundations of the theory. This feature of TPACK survey instruments limits their utility in areas outside the initial context for which the instruments were designed with significant adaptations.

The Schmidt et al. (2009) survey was designed to measure preservice early childhood education (ECE) teachers TPACK. Thus, the items address mathematics, science, literacy and social studies content, which is commonly taught in ECE. The survey of preservice teachers' knowledge of teaching and technology (TKTT) is employed more often in research studies given the prevalence of early childhood education programs. Because the population of interest for this survey is relatively similar in demographics many researchers take advantage of the convenience of the TKTT survey. The TKTT is an ideal instrument for summarizing the effects of university instruction on preservice teacher TPACK given the strong validity and reliability across multiple administrations coupled with model ECE design features. The design of each of these surveys although very specific, is consistent with the nature of the TPACK framework.

The specific nature of the available TPACK instruments may limit the broader applications to different context (Abbitt, 2011), but a universal survey instrument is not available, neither is it reflective of the TPACK framework. Although several instruments currently exist to measure teacher TPACK, studies summarizing the current preservice teacher TPACK knowledge base are elusive. Measurement is further complicated by the differences present in the philosophies and practices used in preservice teacher education programs. The lack of research synthesis is partly attributed to the context specific nature of the TPACK framework that limits the numbers of studies that can reasonably be compared.

Despite these limitations the need for a valid and reliable measure of teacher TPACK is imperative (Mishra & Koehler, 2006; Schmidt et al., 2009). The survey developed by Schmidt et al. (2009) is the most universally used survey, and encompasses most of the aspects of TPACK associated with preservice teacher education. Further the survey of preservice teachers' knowledge of teaching and technology was utilized or adapted in numerous studies to assess TPACK from 2009 to the present (Abitt, 2011; Michelle, 2013; Wang, Crawford, Niederhauser, 2013; Voogt et al., 2011). This survey is not perfect, but very appropriate for the description of preservice teacher TPACK given its support in the literature. In addition, the instrument is robust, with strong and consistently reliability across a multitude of diverse administrations.

Problem Formation

Although many scholars posit that the TPACK framework is a viable model for the development and evaluation of teaching with technology (Archambault & Crippen, 2009; Doering, Scharber, & Miller, 2009; Harris, Mishra, & Koehler, 2009), many incongruities exist between the theoretical and empirical strengths of the model. Theoretical criticisms of the TPACK framework focus on its multiple divergent conceptualizations and definitions and its unclear demarcation of the boundaries between constructs (Angeli & Valanides, 2009; Archambault & Crippen, 2009; Cox, 2008; Cox & Graham, 2009; Jimoyiannis, 2010). The TPACK empirical considerations focus on three issues: the validity and reliability of the current measurement instruments, the context-specific nature of TPACK instruments, and the abundance of non-triangulated self-reported data (Abbit, 2011; Archambault & Barnett, 2010; Lawless & Pellegrino, 2007). These theoretical and empirical considerations are akin to conclusions drawn from meta-analytic thinking and research. However, because the TPACK framework is in its infancy, compared to established theoretical frameworks, sufficient numbers of related quantitative studies remain elusive. Due to the current lack of relevant TPACK data, inference from meta-analytic statistical methodologies is not feasible. Meanwhile, confidence intervals (CIs) can serve as a meta-analytic lens for summarizing quantitative TPACK data.

Confidence Intervals as a Meta-Analytic Lens to Summarize Quantitative Data

Confidence intervals (CIs) provide a meta-analytic lens to summarize quantitative data from multiple samples. Moreover, CIs foster meta-analytic thinking by affording researchers the opportunity to examine plausible values across samples, by facilitating the identification of substantive overlap between the ranges of plausible values for parameters from multiple studies (Zientek, Ozel, Ozel, & Allen, 2012, p. 283). The utilization of CIs as an inferential research synthesis tool is relative new. However, researchers are beginning to realize the analytical potential inherent in this research methodology. In *Characterizing the Mathematics Anxiety Literature Using Confidence Intervals as a Literature Review Mechanism*, Zientek, Yetkiner, and Thompson characterized the effect sizes of 45 studies by graphing confidence intervals. Using descriptive statistical data from each of the studies, the researchers computed the 95% confidence intervals for each study and graphically displayed the data using the Microsoft Excel Stock Option (Zientek, Yetkiner, & Thompson, 2010). Then, based on the interpretation principles posited by Cumming and Finch (2005), the researchers drew conclusions from the graphical representations of the data. This study was not a meta-analysis, but rather represents an example of the meta-analytic thinking that is realized through the use of CI as inferential research synthesis tools.

According to Moore and McCabe (2003), "a level C confidence interval for a parameter is an interval computed from sample data by a method that has probability C of producing an interval containing the true value of the parameter" (p. 420) Appropriately, a 95% CI has a 95% likelihood of containing the true population parameter. CIs allow researchers to approximate population characteristics, such as mean achievement of a standardized test by comparing multiple sample estimates across individual studies. Thus, a CI is an inferential rather than descriptive tool, because the CI estimates the true value of the parameter in the population (Finch & Cumming, 2009). Cumming and Finch (2001) suggest four reasons to use CIs:

- CIs provide point and interval information that is accessible and comprehensible, which supports substantive understanding and interpretation.
- There is a direct link between CIs and NHST.
- CIs support meta-analytic thinking focused on estimation.
- CIs communicate information about a study's precision.

Confidence intervals are generally calculated and interpreted for point estimates, such as means, but effect-size point estimates are also feasible and meaningful. According to Thompson (2002), CIs for effect sizes are exceptionally valuable because they facilitate both meta-analytic thinking and the elucidation of intervals, via comparisons with the effect intervals reported in related prior studies (p. 25).

Statistical significance is measured in terms of *p* values, but the practical or clinical significance of a study is measured in terms of effect sizes. Effect sizes are typically interpreted two ways. The first interpretation is magnitude or size of the result (Callahan & Reio, 2006). This interpretation examines the extent to which objects in a study differ from the null hypothesis (Thompson, Diamond, McWilliam, Snyder, & Snyder, 2005, p. 185). The second interpretation suggest that effect sizes represent the strength of association between the independent and dependent variables. Although effect sizes are typically interpreted in only one of two distinct categories, more than 40 effect sizes are recognized in the literature (Kirk, 1996). However, the following six are commonly used and interpreted in social science research: Cohen's *d*, Pearson *r*, R^2, η^2, ω^2, and Cramer's *V* (Zientek, Ozel, Ozel, & Allen, 2012).

CIs provide valuable parameter-estimation capabilities, which are essential for the empirical validation and refinement of the TPACK conceptual framework. Many studies have sought to synthesize the preservice teacher TPACK literature through a qualitative lens. Studies that employ a meta-analytic lens to examine the effects of university classroom instruction on TPACK, however, remain elusive.

Purpose

The goals of this study are to summarize the current literature on the effects of university classroom instruction on preservice teacher TPACK in order to provide implications for researchers, teacher educators, and administrators. Further, this study provides an illustration of the use of confidence intervals as a research synthesis mechanism. This study aggregates the research on preservice teacher TPACK that has utilized the Survey of Preservice Teachers' Knowledge of Teaching and Technology (TKTT). The TKTT, a survey instrument designed specifically to measure preservice teacher TPACK, has an internal reliability that ranges from .80 to .92 (Schmidt et al., 2009). The individual reliability levels for content knowledge, pedagogy knowledge, pedagogical content knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge are .85, .84, .85, .86, .80, and .92, respectively (Schmidt et al.). The survey is scored on a 5-point Likert scale, where a score of 1 is assigned to *strongly disagree* and a score of 5 is assigned to *strongly agree*. The scores within each construct are then averaged, and the average constitutes the score for that construct. Although the TKTT is only one of many surveys available to measure teacher TPACK, it is the most suitable for this study because of its broad applications across preservice teaching and its relative consistency. This study seeks to estimate the effectiveness of university classroom instruction on preservice teacher PCK, TPK, TCK, and TPACK.

The results of the study will provide parameter estimates for the TPACK constructs, measures of study precision, and implications for multiple stakeholders.

Method

Search Strategies

To locate studies that measured TPACK using the TKTT survey, we applied a five-step process. As Mishra and Koehler (2006) are generally recognized as the developers of the TPACK framework, the literature search began at the "TPACK bibliography" section of the TPACK.org website currently maintained by Mishra. This process yielded 294 papers pertaining to TPACK. Of these, 57 used a survey instrument to measure TPACK. Next, we searched four databases from 2009 until 2011 using the keywords *TPACK, TPCK, technological pedagogical content knowledge*, and *preservice teachers*. We selected an initial year of 2009, even though TPACK was first proposed by Pierson in 2001 because the TKTT was not available until 2009. In addition, we searched the electronic databases EBSCO, ERIC, and ProQuest Dissertations and Theses using the search terms *TPACK, TPCK*, and *technological pedagogical content knowledge*. The combined EBSCO and ERIC search produced 58 scholarly (peer-reviewed) journal articles published between 2009 and 2012. Similarly, the ProQuest Dissertations and Theses search produced 25 published dissertations. Of these 83 journal articles and dissertations, 16 unique journal articles and 6 unique dissertations used a survey method to measure the TPACK of preservice teachers. The overlap between the articles located in the TPACK bibliography and the other search processes accounts for the significant reduction in the number of studies. Lastly, we selected other articles were selected from the references cited within the retrieved studies.

Inclusion and Exclusion Criteria

These procedures yielded 22 appropriate articles, conference presentations, theses, and dissertations. We then read the Methodology and Results sections to establish the studies' pertinence. We considered a work pertinent

Table 1. Study Presentation Order in Figures and Results

	Study Organization			
Study	*PCK*	*TPK*	*TCK*	*TPACK*
Abitt (2011)	1	1	1	1
Baran, Chuang, & Thompson, (2011)	2	2	2	2
Chai, Koh, & Tsai (2010)				3
Chai, Koh, Tsai, Wee, & Tan (2011)		3		4
An, Wilder, & Lim (2011)	3	4	3	5
Koh, & Divaharan, (2011)				6
Nordin, Morrow, & Davis (2011)	4	5	4	7
Schmidt, D. et al. (2009)	5	6	5	8

Note: Numbers represent the order/assignment of each study in the results and figures. Thus, data from Abitt (2011) represents study 1 data in the subsequent discussions.

if (a) the study used the TKTT survey to measure TPACK, (b) the study was conducted in a college or university setting with preservice teachers, (c) the article provided sufficient population details to categorize the sample accordingly, and (d) the article provided statistical data (such as the mean, standard deviation, and sample size) or the data could be obtained reasonably. After we reviewed each article, the initial pool of 22 articles was reduced to 8 studies that met all the criteria for this study (Abitt, 2011; An, Wilder, & Lim, 2011; Baran, Chuang, & Thompson, 2011; Chai, Koh, & Tsai, 2010; Chai, Koh, Tsai, & Wee Tan, 2011; An, Wilder, & Lim, 2011; Koh, & Divaharan, 2011; Schmidt et al., 2009). Table 1 lists the study presentation order for the results and figures included in the study.

Statistical Methods and Procedures

To compare the various CIs across the eight studies, we chose the conventional 95% confidence level because it was the most common. Fortunately, all of the selected studies provided the information pertinent to their CI calculations; thus, no other information was needed. Traditionally, the Stock option in Microsoft Excel is used to create the graphical displays of the CIs for means. Because this study utilizes CIs for mean differences, however, we analyzed the data in Exploratory Software for Confidence Intervals (ESCI).

Statistics, CIs for statistics, and effects sizes are generally easy to obtain with the correct formulas, but the CIs of effect sizes must be estimated through computer-intensive iteration procedures (Thompson, 2007). Statistical packages and other applications can be utilized to perform the appropriate procedures (Algina, Keselman, & Penfield, 2005; Cumming & Finch, 2001; Smithson, 2001). We collected the original pretest and posttest means, standard deviations, sample sizes, and p values for each construct from the original studies. We entered this information in ESCI, which then generated the CI data. We selected ESCI because it runs within Excel, produces estimates based on various inputs, and generates a visually appealing graph that facilitates interpretation and comprehension. Because some studies focused on particular TPACK constructs and excluded others, there are some variations between the numbers of studies presented in each CI.

We compared the point and interval estimates for the individual mean effect sizes for each study to the other studies for each of the four TPACK constructs. The purpose of this comparison was threefold. First, it assesses the precision of the point and interval estimates, in comparison to other studies. Second, it assesses the reasonableness of the mean effect-size point estimates across studies. Both of these assessments are performed by visual inspection and are, to a certain degree, subjective, but they are guided by sound theory. Third, this method allows a visual characterization of the strength of the relationship between university instruction and preservice teacher TPACK.

The precision of the point estimate depends on the margin of error. According to Cumming and Finch (2005), the CI is a range that centers on M and extends for a distance w (width) on either side of M, where w is called the *margin of error* (p. 170). Therefore, CIs with smaller margins of error are more precise. The margin of error is based on the standard error and is a function of the SD and n, as seen in the formula for standard error: $SE = SD/\sqrt{n}$ (Cumming & Finch). CIs that have narrow widths are more precise and tend to use large sample sizes or smaller SDs. This logic holds true for the studies presented in this analysis. Because the sample sizes in some of the studies were relatively small, comparing the point and interval estimates across all the studies will help ascertain the relative precision of the estimates.

Results

The median year of publication was 2011, with six studies published in 2011, one study published in 2010, and one study published in 2009. The majority of the participants were early childhood education students (cited in six studies); the remainder of the participants were secondary education students. The practical and statistical significance statistics for each construct are included in Tables 2 through 5 (pp. 160–161).

Table 2 presents the practical and statistical significances for student PCK. We calculated he pooled mean difference (for all five studies), which measures preservice teacher PCK, in Microsoft Excel by weighting each effect-size measure by its corresponding sample size. We achieved this by calculating the sum of the product of each effect size and its corresponding sample size, using that product as the dividend, and then dividing by the sum of all the sample sizes. The resulting pooled mean difference effect size was 0.33. The data in Table 2 suggest that the effect sizes for PCK measured in the included studies ranged from 0.24 to 1.43. All of the studies included in Table 1 had statistically significant results at the 0.05 level of statistical

Table 2. Practical and Statistical Significance Statistics for Student PCK

	Results			
Study	*d*	*N*	*p* calc	CI for *d*
1	0.24	180	0.000*	0.12 to 0.36
2	0.71	45	0.000*	0.48 to 0.94
3	0.17	112	0.002	0.07 to 0.27
4	0.29	87	0.002	0.11 to 0.47
5	1.43	18	0.012	0.35 to 2.51

Note. Pooled $d = 0.33$; $n = 442$.

Table 3. Practical and Statistical Significance Statistics for Student TPK

	Results			
Study	*d*	*N*	*p* calc	CI for *d*
1	0.38	180	0.000*	0.28 to 0.48
2	0.26	45	.064	-0.016 to 0.54
3	0.01	343	.826	-0.08 to 0.10
4	0.18	112	0.024	0.02 to 0.34
5	0.34	87	0.000*	0.20 to 0.48
6	1.43	18	0.003	0.56 to 2.30

Note: Pooled $d = 0.20$; $n = 785$.

significance. Some *p* values were extremely small, which is indicated by an asterisk following the thousandth place in the table.

Table 3 presents the practical and statistical significance statistics for student TPK. The data in Table 3 have a slightly lower pooled mean difference effect size of 0.20. The data ranged from 0.38 to 1.43. In addition, Studies 2 and 3 did not yield statistically significant differences at the 0.05 level of statistical significance.

Table 4 presents the practical and statistical significance statistics for TCK. The TCK construct has the largest pooled mean difference of all the constructs examined in this study. Thus, the effect of university classroom instruction was largest for this construct, as seen in the mean difference of 0.70.

The overarching TPACK framework was the most widely examined construct, and the results of the pooled effect size estimate were based on a sample of 1150 preservice teachers. The pooled mean difference for TPACK represents a moderate effect size measure of 0.44. This conclusion is based on the effect size magnitude benchmarks suggested by Cohen (1992), by which an effect size of 0.20 is categorized as small, .50 as medium, and .80 as large.

The results of this study are presented in Figures 2 through 5 (p. 162–163). Figure 2 shows the mean difference effect sizes for pedagogical content knowledge (PCK). A subjective examination of the mean difference CIs,

Table 4. Practical and Statistical Significance Statistics for Student TCK

	Results			
Study	*d*	*N*	*p* calc	CI for *d*
1	0.88	180	0.000*	0.75 to 1.01
2	0.87	45	0.000*	0.57 to 1.20
3	0.2	112	0.005	0.06 to 0.34
4	0.88	87	0.000*	0.69 to 1.07
5	0.64	18	0.129	-0.21 to 1.49

Note: Pooled *d* = 0.70; *n* = 442.

Table 5. Practical and Statistical Significance Statistics for Student TPACK

	Results			
Study	*d*	*N*	*p* calc	CI for *d*
1	0.6	180	0.000*	0.47 to 0.73
2	0.59	45	0.000*	0.28 to 0.90
3	0.45	365	0.000*	0.33 to 0.57
4	0.35	343	0.000*	0.26 to 0.44
5	0.29	112	0.000*	0.16 to 0.42
6	0.51	87	0.000*	0.35 to 0.67
7	0.57	18	0.197	-0.33 to 1.47

Note: Pooled *d* = 0.44; *n* = 1150.

presented in Figure 2, suggests that the mean difference PCK effect sizes range between approximately 0.15 and 0.49. The widths of the confidence bands are reasonable measures of the precision of the point estimates. Studies 2 and 5 provide considerably less precise estimates of the mean difference effect-size point estimates than the other studies examined. The wide widths of these CIs indicate either small sample sizes or large standard deviations in student effect size scores.

Figure 3 presents the mean difference effect size CIs for technological pedagogical knowledge (TPK). The magnitude of association between preservice teacher TPK and university instruction is not as consistent for this construct, as seen in the decreased overlap between the confidence bands in Figure 3. The best estimate of the population mean difference effect size is between 0.1 and 0.4. Study 6 is the only one in this subset that falls outside of the cutoff for this construct. Its mean difference effect size CI does not overlap with any of the other studies in the figure. Further, given the small sample size of 18, the width of the confidence band is much larger than in the other studies.

The results for the TCK domain effectiveness are depicted in Figure 4, which presents the 95% CIs for the mean difference effect sizes for the TCK domain. The population's mean difference effect size for teacher education programs' influence on TCK falls between approximately 0.6 and 0.9. One study in this analysis falls outside the cutoff, indicating that the results are

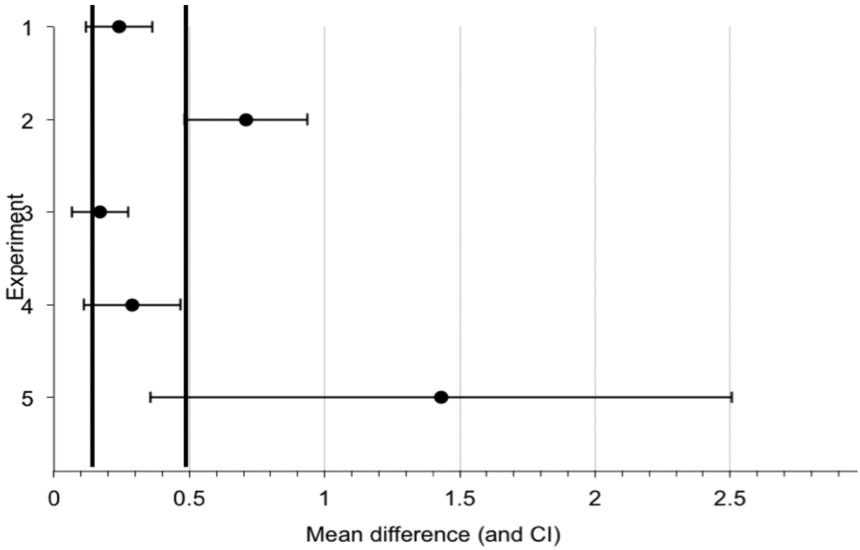

Figure 2. The mean difference effect size (95% CI) for preservice teacher PCK.

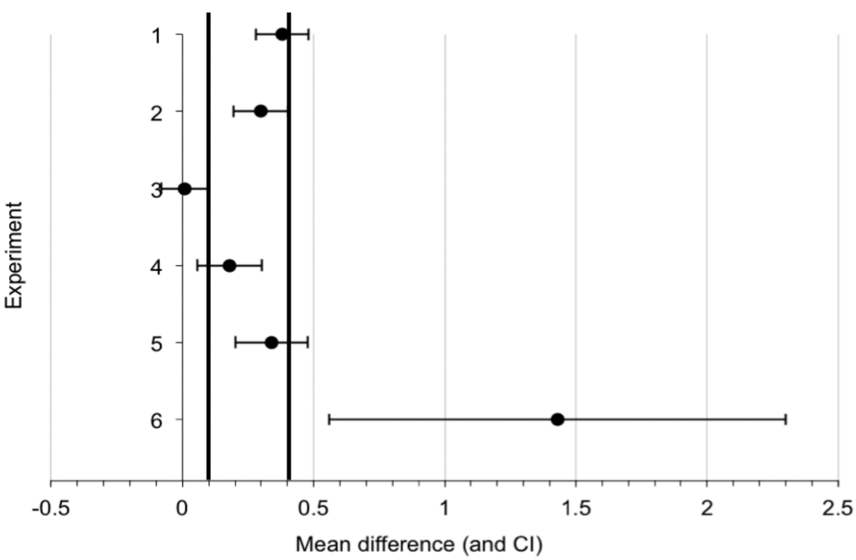

Figure 3. The mean difference effect size (95% CI) for preservice teacher TPK.

relatively consistent across studies, as demonstrated by the overlap of the confidence bands presented in Figure 4. The widths of the confidence bands, however, suggest some questions concerning the precision of the measurements for the TCK domain.

Technological pedagogical content knowledge (TPACK) was the final domain assessed in this analysis. The data in Figure 5 show that the

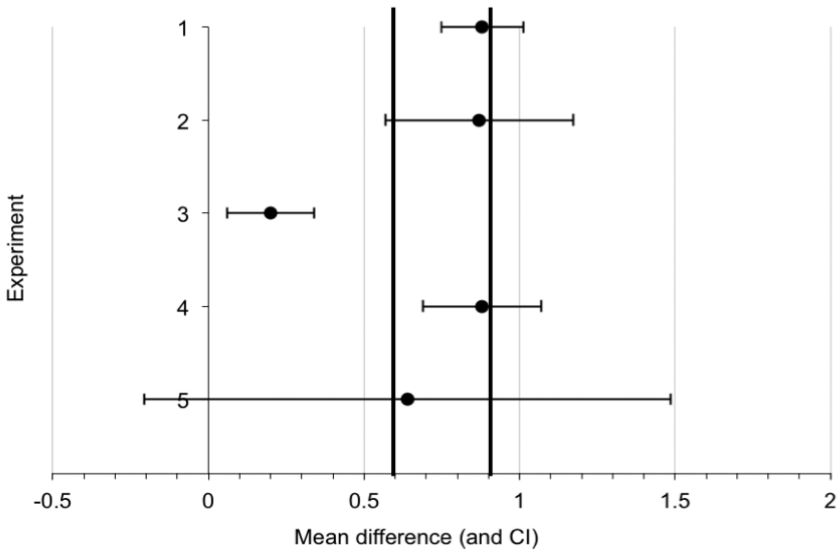

Figure 4. Mean difference effect size (95% CI) for preserviceteacher TCK.

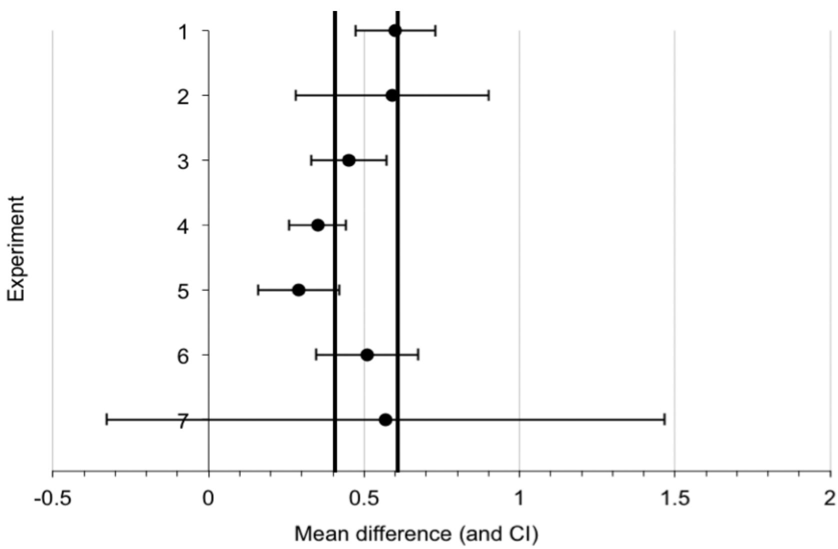

Figure 5. The 95% CIs for mean difference effect sizes for the TPACK domain.

population's mean difference effect size for TPACK is between 0.4 and 0.6. The TPACK effect sizes are considerably more consistent, given the larger overlap of the different confidence bands. Measurement precision varies among the different studies. Studies 2 and 7 have the widest bands, which signify less precision in the measurement of the mean difference effect-size point estimate.

Summary of Results

The results of this study indicate that preservice teacher education influences all domains of teacher TPACK. We interpreted the effect sizes in this study as the relationship between university instruction and preservice teacher TPACK. The relationships between teacher education and each domain of TPACK (PCK, TPK, TCK, and TPACK), however, vary in strength and consistency. For evaluative purposes we implemented the Cohen (1988) benchmarks to provide a context for the magnitude of the influence of university instruction on preservice teacher TPACK. Cohen (1988) suggests that 0.20, 0.50, and 0.80 represent a small, medium, and large effect size respectively. The TCK domain revealed the largest estimate for population effect size. The pooled pretest/posttest difference for TCK was .70, and the population estimates ranged between 0.6 and 0.9. These medium to large effect sizes represent a strong association between preservice teacher TCK and the instruction they receive in their university coursework. The confidence bands for TCK, however, were among the widest bands observed in this study. This lack of precision could have resulted from large item response variations, small sample sizes, or inconsistent measurements of the construct. Nevertheless, the data suggest that a strong relationship exists between preservice teacher TCK and university instruction. This relationship may suggest that preservice teachers' initial TCK is weak and that university instruction is an effective method for increasing knowledge in this domain. The latter conclusion parallels the results of similar studies and reports that suggest that although many preservice teachers are "digital natives," it is not safe to assume that basic technology skills translate to the context of classroom practice (Brzycki & Dudt, 2005; Lei, Conway, & Zhao, 2008; *Education Week*, 2007).

We saw the smallest estimates for population effect size in the TPK construct. The results of this study suggest that the mean difference effect of university instruction on preservice teacher TPK is between approximately 0.1 and 0.4. Moreover, this construct was consistently and precisely measured, as shown by the narrow confidence bands and the significant overlap between the point estimate's CIs. These data suggest that the relationship between preservice teacher classroom instruction and TPK, although small, was reliably measured. Prior researchers suggest that TPK is a major focus of many teacher education programs with regard to technology integration (Koh & Divaharan, 2011; Figg & Jaipal, 2009). However, results of this study indicate preservice teacher TPK is less responsive to current university classroom practices. Thus, these results suggest that preservice teacher TPK is a more static construct; hence, an examination of the current preservice teacher technology pedagogy instructional praxis is warranted to obtain significant changes in student knowledge.

We also measured preservice teacher PCK in this study, but the results, although relatively precise and consistent, were only slightly larger than the results for TPK. These results are indicative of the lack of emphasis on isolated pedagogical skills in technology methods courses. The coursework presented in the preservice teacher classroom tends to focus on technology knowledge integration, not general pedagogical practices. Thus, it is not surprising that the relationship between this construct and the coursework is weaker than the relationships between the other constructs. Furthermore, according to Abell (2008) the development of PCK requires the transformation of subject matter knowledge, pedagogical knowledge, and context knowledge. These vastly different types of knowledge require authentic educational tasks to promote the transformation and integration of this knowledge. Additionally, teachers with a strong pedagogical content knowledge background tend to utilize technology more effectively in the classroom (Valanides & Angeli, 2008). Thus, PCK is an integral part of the TPACK framework that must be cultivated in conjunction with the other constructs.

The final construct assessed in this study was overall teacher TPACK, which represents the best measure of a teacher's ability to understand the affordances and constraints of technology within the realm of instruction. The data demonstrate that this construct was the most accurately measured, as demonstrated by the consistency in the confidence bandwidth and the significant overlap among all measurements. Further, the preservice teacher population's estimated mean difference effect of classroom instruction ranged between 0.4 and 0.6. The pooled mean difference for this construct was 0.44, marking the second largest pooled mean difference observed in this study. These data suggest that the TPACK construct can be influenced by university classroom instruction with relative consistency and confidence. An examination of TPACK in relation to practice is needed to bridge the gap between theory and practice (Mouza & Karchmer-Klein, 2013). Although this study does not attempt to fill this void, the results provide implications to influence practice and support further investigation.

Discussion

The nature of TPACK as a fluid educational framework may contribute to the differences across domains. However, this study suggests that preservice teacher TPACK can be measured—using preservice teacher knowledge of teaching and technology (TKTT)—with consistency and precision in many construct domains. Other domains, however, need some refinement and further study. In addition, this study provides several implications for preservice teacher technology education. Most accredited teacher education programs are required to offer an educational technology course (Kleiner et al., 2007). This course represents the extent to which most preservice teachers will interact with technology in their undergraduate coursework; thus, the results of this study may help adjust the focus these courses' content on universally problematic TPACK constructs.

Implications for Practice

First, pedagogy must be moved to the forefront of the technology integration course. Technology integration is a difficult concept to teach effectively. The complexity of teaching how to teach with technology stems from the need to teach general technology utilization skills for a given tool as well as the pedagogical constraints and affordances of the tool in a subject matter specific context (Angeli & Valanides, 2013). Consequently, the constructs least influenced by technology education coursework were the two pedagogical components of the TPACK framework (PCK and TPK); thus, this area should receive further consideration in technology education curricula planning. Preservice teachers' lack of PCK and, more specifically, TPK necessitates a reconfiguration of university curriculum guides to reflect the importance of early exposure to technology integration coursework. Technology integration courses are necessary and should occur before methods courses to allow preservice teachers an opportunity to develop and extend their knowledge (Allsopp, McHatton, & Cranston-Gingras, 2009; Chitiyo & Harmon, 2009; Hsu, 2012). Further, an examination of current technology integration practices is necessary.

Many instructional models currently exist to develop preservice teacher TPACK through instructional technology courses. These models incorporate microteaching, video lesson reflections, student interviews, and lesson planning (Akkoc, 2011; Erdogan & Sahin, 2010; Pierson, 2001). TCK and TPACK, however, had relatively stronger relationships with preservice teacher university instruction. This suggests that the current approaches are relatively effective but should be refined to increase the depth and breadth of the instruction. Cross-curricular planning and alignment has significant implications for the development of preservice teacher technology integration practices and skills (Hofer & Gandgenett, 2012). As methods instructors and technology instructors begin to coordinate and develop authentic cross-curricular task inconsistences can be better assessed.

Limitations of the Study

A limitation of this study is lack of a substantial number of representative studies. Although the survey of TKTT is widely used to assess preservice teacher TPACK, many studies did not include sufficient data to calculate a mean difference effect size. Moreover, to better align this study to the context-specific nature of TPACK, we implemented a strict inclusion protocol, which further restricted the sample of pertinent articles. Given the small sample size, traditional meta-analysis methodology was inappropriate. Although this study was not reflective of a traditional meta-analysis, we implemented the Meta-Analysis Reporting Standards (MARS). We did not conduct a moderator and mediator analysis because it was not warranted, given the methodology implemented in this study.

Recommendations for Future Research

This study presents several implications for further research and investigation. The results presented here suggest that some variations exist in preservice teacher PCK, TPK, TCK, and TPACK, both before and after university technology integration coursework. Possible sources of the score deviations should be identified and examined as mediating factors. Possible mediating factors include (a) instructional design, (b) type of instruction, (c) student population demographics, and (d) length of treatment. These issues represent a small subset of factors that could influence classroom instruction's effect on teacher TPACK constructs. Several studies have already investigated the influence of instructional design and type of instruction on preservice teacher technology integration (Jang & Chen, 2010; Kramarski & Michalsky, 2009). However, more studies are needed to develop sound theories and explanations for the trends presented in this study. Future researchers can build upon such previous works to investigate the influence of these and other factors on TPACK.

In addition to identifying and addressing possible mediating factors, researchers could also extend this research synthesis methodology to other TPACK measurements. This study focused on synthesizing data from the Survey of Preservice Teachers' Knowledge of Teaching and Technology. We did not include other instruments to avoid any possible measurement inconsistency. However, separate analysis of other self-reported survey instruments, rubrics, or observations would provide a means to compare the precision and accuracy of TPACK measurement across several instruments. Although effect sizes can combine across studies, the context and measurement of each construct must be operationalized in a similar manner. As the measurement of TPACK evolves, the reasonableness of combining studies across multiple measures and context may be realized. However, given the lack of consistent conceptualizations to support the aggregation of TPACK data, an analysis of this nature is premature.

Author Notes

Jamaal R. Young is an assistant professor in the Department of Teacher Education and Administration, University of North Texas, Denton. His research interests focus on the intersectionality of technology, culture, and mathematics achievement. Please address correspondence regarding this article to Jamaal Young, Department of Teacher Education and Administration, University of North Texas, Denton, Texas 76206. Email: Jamaal.young@unt.edu

Jemimah L. Young is an assistant professor in the Department of Teacher Education and Administration at University of North Texas, Denton. Her research interests focus on preparing preservice teachers to meet the needs of all students, exploration of alternative cultures in education, and culturally responsive education and achievement of children of color.

Christina Hamilton is a graduate of University of North Texas, Denton. Her research interests focus on the use of culturally relevant technologies in the pedagogical practices of mathematics teacher educators, the technological pedagogical content knowledge of teacher educators, and the mathematics achievement of students of color.

References

*Abitt, J. T. (2011a). An investigation of the relationship between self-efficacy beliefs about technology integration and technological pedagogical content knowledge (TPACK) among preservice teachers. *Journal of Digital Learning in Teacher Education, 27*(4), 134–143.

Abbit, J. T. (2011b). Measuring technological pedagogical content knowledge in preservice teacher education: A review of current methods and instruments. *Journal of Research on Technology in Education, 43*(4), 281–300.

Agyei, D. D., & Keengwe, J. (2012). Using technology pedagogical content knowledge development to enhance learning outcomes. *Education Information Technology*, Advance online publication. Retrieved from http://dx.doi.org/10.1007/s10639-012-9204-1

Agyei, D., & Voogt, J. (2011). Determining Teachers' TPACK through observations and self-report data. In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2011* (pp. 2314–2319). Chesapeake, VA: AACE.

Algina, J., Keselman, H. J., & Penfield, R. D. (2005). Effect sizes and their intervals: The two-level repeated measures case. *Educational and Psychological Measurement, 65*, 241–258.

Allsopp, D.H., McHatton, P.A., & Cranston-Gingras, A. (2009). Examining perceptions of systematic integration of instructional technology in a teacher education program. *Teacher Education and Special Education, 32*(4), 337–350.

*An, H., Wilder, H., & Lim, K. (2011). Preparing elementary pre-service teachers from a non-traditional student population to teach with technology. *Computers in the Schools, 28*(2), 170–193.

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning, 21*(4), 292–302.

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education, 52*(1), 154–168.

Angeli, C., & Valanides, N. (2013). Technology mapping: An approach for developing technological pedagogical content knowledge. *Journal of Computing Research, 48*(2), 199–221.

Archambault, L. M., & Barnett, J. H. (2010). Revisiting technological pedagogical content knowledge: Exploring the TPACK framework. *Computers & Education*, 55, 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.

*Baran, E., Chuang, H., & Thompson, A. (2011). TPACK: An emerging research and development took for teacher educators. *The Turkish Online Journal of Educational Technology, 10*(4), 370–377.

Bracewell, R. J., Sicilia, C., Park, J., & Tung, I. (2007, April). *The problem of wide-scale implementation of effective use of information and communication technologies for instruction: Activity theory perspectives. Tracking adoption and nonadoption of ICT activities by teachers*. Paper presented at the 2007 Annual Meeting of the American Educational Research Association (AERA), Chicago, IL.

Britten, J. S., & Cassady, J. C. (2005). The Technology Integration Assessment Instrument: Understanding planned use of technology by classroom teachers. *Computers in the Schools, 22*(3), 49–61.

Brzycki, D., & Dudt, K. (2005). Overcoming barriers to technology use in teacher preparation programs. *Journal of Technology and Teacher Education, 13*(4), 619–641.

Butt, G. (2006). *Lesson planning (2nd ed).* New York: Continuum International Publishing Group.
Callahan, J. L. & Reio, T, G. (2006). Making subjective judgments in quantitative studies: The importance of using effect sizes and confidence intervals. *Human Resource Development Quarterly, 17*(2), 159–173.
*Chai, C. S., Koh, J. H. L., & Tsai, C. C. (2010). Facilitating preservice teachers' development of technological, pedagogical, and content knowledge (TPACK). *Educational Technology & Society, 13*(4), 63–73.
*Chai, C. S., Ling Koh, J. H., Tsai, C., & Wee Tan, L. L. (2011). Modeling primary school pre-service teachers' technological pedagogical content knowledge (TPACK) for meaningful learning with information and communication technology (ICT). *Computers & Education, 57*, 1184–1193.
Chitiyo, R., & Harmon, S. W. (2009). An analysis of the integration of instructional technology in preservice teacher education in Zimbabwe. *Educational Technology Research and Development, 57*(6), 807–830.
Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.
Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112, 155–159.
Cox, S. (2008). *A conceptual analysis of technological pedagogical content knowledge.* Unpublished doctoral dissertation. Provo, UT: Brigham Young University.
Cox, S., & Graham, C. R. (2009). Diagramming TPACK in practice: Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge. *Tech Trends, 53*(5), 60–69.
Cumming, G., & Finch, S. (2001). A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. *Educational and Psychological Measurement, 61*(4), 532–574.
Cumming, G., & Finch, S. (2005). Inference by eye: Confidence intervals and how to read pictures of data. *American Psychologist, 60*(2), 170–180.
Doering, A., Scharber, C., & Miller, C. (2009). GeoThentic: Designing and assessing with technology, pedagogy, and content knowledge. *Contemporary Issues in Technology and Teacher Education, 9*(3), 316–336.
Education Week. (2007). *Technology counts 2007*. Retrieved September 10, 2008, from http://www.edweek.org/media/ew/tc/2007/tc07_press_release.pdf
Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, 53, 25–39.
Figg, C., & Jaipal, K. (2009). Unpacking TPACK: TPK characteristics supporting successful implementation. In I. Gibson, R. Weber, K. McFerrin, R. Carlsen, & D. A. Willis (Eds.), *Proceedings of Society for Information Technology Teacher Education International Conference 2009* (pp. 4069–4073). Chesapeake, VA: AACE. Retrieved from http://www.editlib.org/p/31295
Finch, S., & Cumming, G. (2009). Putting research in context: Understanding confidence intervals from one or more studies. *Journal of Pediatric Psychology, 34*(9), 903–916.
Franklin, C. (2004). Teacher preparation as a critical factor in elementary teachers: Use of computers. In R. Carlsen, N. Davis, J. Price, R. Weber, & D. Willis (Eds.), *Society for Information Technology and Teacher Education Annual* (pp. 4994–4999). Norfolk, VA: Association for the Advancement of Computing in Education.
Graham, C. R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education, 57*, 1953–1960.
Graham, C. R., Burgoyne, N., & Borup, J. (2010). The decision-making processes of preservice teachers as they integrate technology. In C. Crawford, D. A. Willis, R. Carlsen, I. Gibson, K. McFerrin, J. Price, & R. Weber (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2010* (pp. 3826–3832). Chesapeake, VA: AACE.

Harris, J., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment rubric. In C. Crawford, D. A. Willis, R. Carlsen, I. Gibson, K. McFerrin, J. Price, & R. Weber (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2010* (pp. 3833–3840). Chesapeake, VA: AACE.

Harris, J., 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.

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 Teaching, 45*(1), 83–106.

Hofer, M., Grandgenett, N., Harris, J. & Swan, K. (2011). Testing a TPACK-based technology integration observation instrument. In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2011* (pp. 4352–4359). Chesapeake, VA: AACE.

Hsu, P. (2012). Examining the impact of educational technology courses on preservice teachers' development of technological pedagogical content knowledge. *Teaching Education, 23*(2), 195–213.

Irving, K. E. (2006). The impact of technology on the 21st century classroom. In J. Rhoton & P. Shane (Eds.), *Teaching science in the 21st century* (pp. 3–20). Arlington, VA: National Science Teachers Association Press.

Jamieson-Proctor, R., Finger, G., & Albion, P. (2010). Auditing the TK and TPACK confidence of pre-service teachers: Are they ready for the profession? *Australian Educational Computing, 25*(1), 8–17.

Jang, S. J., & Chen, K. C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. *Journal of Science Education and Technology, 19*(6), 553–564.

Jimoyiannis, A. (2010). Designing and implementing an integrated technological pedagogical science knowledge framework for science teachers professional development. *Computers & Education, 55*(3), 1259–1269. doi:10.1016/j.compedu.2010.05.022

Keating, T., & Evans, E. (2001). Three computers in the back of the classroom: Preservice teachers' conceptions of technology integration. *Proceedings of Society for Information Technology and Teacher Education International Conference* (pp. 1671–1676). Norfolk, VA.

Kereluik, K., Casperson, G. & Akcaoglu, M. (2010). Coding pre-service teacher lesson plans for TPACK. In D. Gibson & B. Dodge (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2010* (pp. 3889–3891). Chesapeake, VA: AACE.

Kirk, R. E. (1996). Practical significance: A concept whose time has come. *Educational and Psychological Measurement, 56*, 746–759.

Kleiner, B., Thomas, N., Lewis, L., & Greene, B. (2007). *Educational technology in teacher education programs for initial licensure.* Washington DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Dept. of Education.

Koehler, M. J., Shin, T. S., & Mishra, P. (2012). 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: IGI Global.

*Koh, J. H., & Divaharan, S. (2011). Developing pre-service teachers' technology integration expertise through the TPACK-developing instructional model. *Journal Educational Computing Research, 44*(1), 35–58.

Kramarski, B., & Michalsky, T. (2009). Three metacognitive approaches to training pre-service teachers in different learning phases of technological pedagogical content knowledge.*Educational Research and Evaluation, 15*(5), 465–485.

Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning: Knowns, unknowns, and ways to pursue better questions and answers. *Review of Educational Research, 77*(4), 575–614.

Lei, J., Conway, P., & Zhao, Y. (2008). *Digital pencils: One to one computing in schools.* Mawhaw, NJ: Lawrence Erlbaum Associates.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 8*(6), 1017–1054.

Mitchell, M. (2013). A comparative study of mathematical content, pedagogy and technology using a paired t-test of the means of seven domains. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2013* (pp. 2273–2278). Chesapeake, VA: AACE.

Moore, D. S., & McCabe, G. P. (2003). *Introduction to the practice of statistics* (4th ed.). New York: W. H. Freeman.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509–523.

Niess, M. L. (2008). Guiding preservice teachers in developing TPCK. In AACTE Committee on Innovation and Technology (Ed.), *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* (pp. 223–250). New York: Routledge for the American Association of Colleges for Teacher Education.

Niess, M. L. (2011). Investigating TPACK: Knowledge growth in teaching with technology. *Journal of Educational computing research, 44*(3), 299–317.

*Nordin, H., Morrow, D., & Davis, N. (2011). *Pre-service teachers' experience with ICT in secondary schools: A case study of one New Zealand context.* Unpublished manuscript, College of Education, University of Canterbury, New Zealand.

Pierson, M. E. (1999). Technology integration practice as a function of pedagogical expertise. Doctoral dissertation, Arizona State University. *Dissertation Abstracts International, 60(03)*, 711 (AAT 9924200).

Pierson, M. E. (2001). Technology integration practice as a function of pedagogical expertise. *Journal of Research on Computing in Education, 33*(4), 413–429.

Sahin, I., Akturk, A., & Schmidt, D. (2009). Impact of preservice teachers' technological pedagogical content knowledge on their vocational self-efficacy beliefs. In G. Ian, W. Roberta, M. Karen, C. Roger, & W. Dee Anna (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2009* (pp. 4137–4144). Chesapeake, VA: AACE.

*Schmidt, D., Baran, E., Thompson, A., Koehler, M., Punya, M., & Shin, T. (2009). Examining preservice teachers' development of technological pedagogical content knowledge in an introductory instructional technology course. In I. Gibson et al. (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2009* (pp. 4145–4151). Chesapeake, VA: AACE.

Schmidt, D., Sahin, E. B., Thompson, A., & Seymour, J. (2008). Developing effective technological pedagogical and content knowledge (TPACK) in preK–6 teachers. In K. McFerrin, R. Weber, R. Carlsen, & D. A. Willis (Eds.), *Proceedings of the Society for Information Technology & Teacher Education International Conference 2008* (pp. 5313–5317). Chesapeake, VA: AACE.

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

Slough, S., & Connell, M. (2006). Dehning technology and its natural corollary, technological content knowledge (TCK). In C. Crawford, D. Willis, R. Carlsen, I. Gibson, K. McFerrin, J. Price, & R. Weber (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference 2006* (pp. 1053–1059). Chesapeake, VA: AACE.

Smithson, M. (2001). Correct confidence intervals for various regression effect sizes and parameters: The importance of noncentral distributions in computing intervals. *Educational and Psychological Measurement, 61*, 605– 632.

Thompson, B. (2002). What the future quantitative social science research could look like: Confidence intervals for effect sizes. *Educational Researcher, 31*(25), 25–32.

Thompson, B. (2007). Effect sizes, confidence intervals, and confidence intervals for effect sizes. *Psychology in the Schools, 44*(5), 423–432.

Thompson, B., Diamond, K. E., McWilliam, R., Snyder, P., & Snyder, S. W. (2005). Evaluating the quality of evidence from correlational research for evidence-based practice. *Exceptional Children, 71*, 181–194.

Valanides, N., & Angeli, C. (2008). Learning and teaching about scientific models with a computer modeling tool. *Computers in Human Behavior, 24*, 220–233.

Voogt, J., Shin, T., Mishra, P., Koehler, M., Schmidt, D., Baran, E., Thompson, A., Wang, W., Alayyar, G., Fisser, P., Agyei, D., Ormel, B., Velthuis, C., Tondeur, J., & Gibson, D. (2011). Teachers' assessment of TPACK: Where are we and what is needed? In M. Koehler & P. Mishra (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2011* (pp. 4422–4426). Chesapeake, VA: AACE.

Wang, W., Crawford, D. & Niederhauser, D. (2013). An investigation of how preservice teachers develop TPACK after content methodology courses. In R. McBride & M. Searson (Eds.), *Proceedings of Society for Information Technology & Teacher Education International Conference 2013* (pp. 5104–5111). Chesapeake, VA: AACE.

Zhao, Y. (2003). *What teachers should know about technology: Perspectives and practices?* Greenwich, CT: Information Age Publishing.

Zientek, L. R., Ozel, Z, E., Ozel, S., & Allen, J. (2012). Reporting confidence intervals and effect sizes: Collecting the evidence. *Career and Technical Education Research, 37*(3), 277–295.

Zientek, L. R., Yetkiner, Z., & Thompson, B. (2010). Characterizing the mathematics anxiety literature using confidence intervals as a literature review mechanism. *The Journal of Educational Research, 103*, 424–438.

Manuscript received February 22, 2013 | Initial decision May 7, 2013 | Revised manuscript accepted June 30, 2013