Spring 4-27-2018

# Initial Evidence of Construct Validity of Data from a Self-Assessment Instrument of Technological Pedagogical Content Knowledge (TPACK) in 2-Year Public College Faculty in Texas

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Recommended Citation
Scott, Kristin C., "Initial Evidence of Construct Validity of Data from a Self-Assessment Instrument of Technological Pedagogical Content Knowledge (TPACK) in 2-Year Public College Faculty in Texas" (2018). *Human Resource Development Theses and Dissertations.* Paper 26.
http://hdl.handle.net/10950/844

# INITIAL EVIDENCE OF CONSTRUCT VALIDITY OF DATA FROM A SELF-ASSESSMENT INSTRUMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) IN 2-YEAR PUBLIC COLLEGE FACULTY IN TEXAS

by

KRISTIN COLLETTE SCOTT

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Human Resource Development

Kim Nimon, Ph.D., Committee Chair

Soules College of Business

The University of Texas at Tyler
April 2018

The University of Texas at Tyler
Tyler, Texas

This is to certify that the Doctoral Dissertation of

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April 12, 2018
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# Dedication

*For teachers everywhere, at every level –*

We all start as beginners.  It is the teacher's dedication to the art and science of excellent teaching and compassion for us, the students, that lifts us all up economically, intellectually, and spiritually.  Let us begin, again.

# Acknowledgements

Without the many positive influences in my life from a plethora of people, I would not have been able to complete a doctoral degree. Some of them are listed below but there was not space or time to acknowledge everyone. If you are not listed, you know who you are and how you gave me strength and energy to keep going.

My dissertation committee, Dr. Kim Nimon (chair), Dr. Jerry Gilley, Dr. Judy Sun, and Dr. Gary Miller, have guided me through this process with profound patience. Dr. Nimon invested countless hours in helping me learn the statistical analyses used in this dissertation, has read numerous bloated drafts, and helped me complete this dissertation in a reasonable time frame. Dr. Gary Miller participated in the expert committee that vetted the survey items and has been a wonderful touch-point on educational issues. Dr. Jerry Gilley and Dr. Judy Sun have given valuable feedback in all phases of this process. Thank you all for helping me successfully complete this study, my dissertation, and my doctoral degree.

My parents, Dr. Charles Richard Scott (deceased) and Dr. Judith Melanie DeLouche Scott Ford showed me that a doctoral degree is a possibility for those persistent enough. I will be honored to wear my mother’s tam as a second generation Ph.D. My daughter, Katherine Anne Elizabeth-Marie Scott, is the reason I keep going even when I want to give up. Katherine Anne, I appreciate all your support and patience even though I know it was very hard for you at times.

Dr. Jerry Gilley, who saw possibility in me when he admitted me to the Ph.D. program in Human Resource Development (HRD). The entire faculty of the Ph.D. program in HRD at The University of Texas at Tyler was excellent as I completed my classes, always pushing me to see beyond the surface. I had no idea how different I would become as a person and a scholar. The efforts of people like Dr. Andrea Ellinger, Dr. Ann Gilley, Dr. Greg Wang, and my dissertation committee members helped me transition from a subject matter expert into a research scholar. Specifically, Dr. Kim Nimon is an extremely gifted statistics teacher. Her well-constructed lessons and activities helped me learn not only how to do the statistical procedures but how to understand the results. I am not gifted in statistics. The learning opportunities Dr. Nimon created and my own dedication to the process helped me achieve knowledge, skills, and abilities I would never have imagined I would possess. She even tolerated a much-needed *Sharknado* (2013) reference in my capstone presentation. I continue to be excited about learning new statistical analyses.

My 2014 cohort members, the *Magnificent 7*, and my older and younger cohort brothers and sisters, thank you for helping me get to the finish line. I am grateful I got to know you and work with you. I hope to continue our collaborations for many years to come.

For all the others who have supported me, given me comfort, and helped me along – Kim Shade, my best friend and girl posse rider; Dr. Larry Mendez, my supervisor and mentor at Tyler Junior College; Dr. Lisa Harper, a mentor and fellow Louisianan woman after my own heart, and countless others, thank you. I could not have done it without your support.

Finally, I acknowledge that without the daily instant message therapy and introspection provided by Wayne S. Froese it would have been a lot harder and less fun. For eight years the virtual window between Texas and Minnesota has been open. It started with *Paleo Zombie Ants* and since then we have talked about work, our families, our personal struggles, railed against the dark forces at work in the world, sought to understand faith, and hashed out everything from basic regression to the Higgs boson. For the last four years, Wayne has listened to the minutia of my doctoral studies, statistical struggles, personal problems, and steadfastly been my friend. I really could not have done it without you, Wayne.

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# INITIAL EVIDENCE OF CONSTRUCT VALIDITY OF DATA FROM A SELF-ASSESSMENT INSTRUMENT OF TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK) IN 2-YEAR PUBLIC COLLEGE FACULTY IN TEXAS

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The Univesity of Texas at Tyler
April 2018

Technological pedagogical content knowledge (TPACK) has been studied in preservice and inservice PK-12 faculty in the U.S. and around the world using survey methodology. Very few studies of TPACK in post-secondary faculty have been conducted and no peer-reviewed studies in U.S. post-secondary faculty have been published to date. The handful of doctoral dissertations that use TPACK survey methodology in U.S. post-secondary faculty failed to test the reliability and validity of their instruments in their sample. The present study is the first reliability and validity of data from a TPACK survey to be conducted with a large sample of U.S. post-secondary faculty, specifically a sample of Texas community college faculty. It is important to find a simple survey tool for Texas 2-year faculty that focuses on the constructs of TPACK in order to evaluate professional development needs in this population. The professorate of 2-year public college faculty in Texas will help their institutions meet the goals of the state's higher education strategic plan, *60x30TX*. In order to do reach the *60x30TX* goals, Texas community college faculty will need to implement learner-centered strategies as well as more technology in their courses. At present, there is no simple, easy, and effective way for faculty or their institutions to assess the faculty's readiness to fulfill these goals. A sequential EFA-CFA process is used to test the Community College TPACK Survey for Meaningful Learning (CC-TSML) for reliability, validity, and model fit. The results indicate that the CC-TSML may be a useful initial tool to help Texas community colleges and their faculty determine where to spend their professional development efforts. Comparisons to other studies indicate that the data from Texas 2-year public college faculty in this sample fit well between PK-16 and university faculty in other cultural contexts.

*Key words:* technological pedagogical content knowledge, TPACK, post-secondary faculty, 2-year public college faculty, community college faculty, sequential EFA-CFA, *60x30TX*

# Chapter One – Introduction

**“Without bold action, Texas faces a future of diminished incomes, opportunities, and resources” (Texas Higher Education Coordinating Board [THECB], 2015, p. v).**

The Texas Higher Education Coordinating Board (THECB) is concerned about the economic future of Texas and believes postsecondary education for its citizens is one way to help ensure the State is economically prosperous (THECB, 2015). In order to help achieve the State’s goals for continued economic success, THECB created the *60x30TX* higher education strategic plan (“60 by 30 Texas”; 2015). The *60x30TX* strategic plan is a roadmap for economic stability and growth for the state, local economies, and private citizens; the plan recognizes the importance of higher education in creating economic prosperity for individuals and their communities (THECB, 2015). This plan focuses on four broad goals to be completed by 2030: (a) 60% of Texans aged 25–34 will have earned a certificate or degree; (b) more Texans, including historically underrepresented minorities (HURMs; see Definitions), economically disadvantaged, and academically underprepared citizens, will complete a certificate or degree; (c) all graduates will complete programs with identifiable marketable skills; and (d) student loan debt for undergraduates “will not exceed 60 percent of first-year wages for graduates of Texas public institutions” (THECB, 2015, p. vi). The present research is designed to test the reliability and validity of an instrument that could be used to evaluate the knowledge, skills, and abilities (KSAs) of the individuals who will primarily be responsible for helping Texas achieve the education goals of *60x30TX*: the faculty at Texas 2-year public colleges, also called community colleges.

In order convey how this chapter informs the present research, it may be helpful to consider how education is similar to manufacturing (see Figure 1). In both manufacturing and education, institutions receive inputs that they alter using processes to create desired outputs. In manufacturing, institutions can set standards for inputs and reject those inputs that fail to meet standards, just as universities can reject substandard inputs by using admission requirements (e.g., high school GPA). However, at Texas public 2-year colleges, which are open-admissions institutions by statute (TEC §130), the institutions must conduct their processes with imperfect input (e.g., academically underprepared students). In education, it is the faculty who are responsible

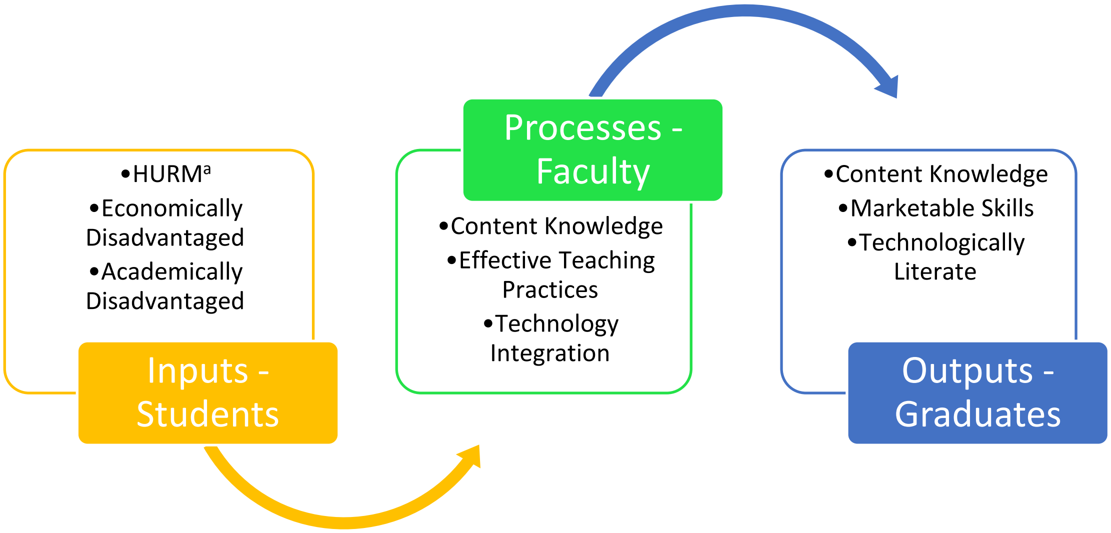

*Figure 1.*Work flow for educational institutions turning inputs into desired outputs as expressed in *60x30TX* (THECB, 2015).
*Note.* a = historically underrepresented minorities (see Definitions).

for processing (i.e., teaching) the inputs (students) to create the desired outputs (graduates). Just as manufacturers identify processes and establish a properly trained workforce to ensure high-quality outputs, educational institutions have the same needs in order to create the desired outputs of graduates. The THECB has identified both learner-centered[1] principles and the use of technology as two of the necessary processes educational institutions should use in successfully meeting the goals of *60x30TX* (THECB, 2015).

The organization of this chapter reflects the inputs → processes → outputs work flow by first examining the inputs (i.e., students) to community colleges across the United States and Texas. Next, the chapter will consider the educational processes known to be effective in creating the desired outputs (graduates), learner-centered principles, and technology integration. This chapter will consider the evolution of Texas faculty credentialing and the development of the 2-year public college system as a way of examining how the human resource component of the educational processing function has developed over time to its present state. The chapter will introduce the theoretical framework of Technological Pedagogical Content Knowledge (TPACK) theory (see Figure 2) that underpins the present research and demonstrate its widespread support,

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[1] In educational literature, texts, and in the Texas higher education strategic plan, the term “student-centered” is often used in place of “learner-centered” (McCombs & Whisler, 1997; THECB, 2015). Constructivism, social constructivism, and related terms are also used in education literature to discuss the theories upon which learner-centered practices are based (McCombs & Whisler, 1997). This researcher prefers the term “learner-centered.” This is the language used with the American Psychological Association’s (APA) principles (APA, 1993; 1995; 1997). The term’s focus is more inclusive, indicating that “the … principles apply to all individuals, from the very young to the very old, from students in the classroom to teachers, administrators, parents, and others influenced by the process of schooling and by other formal and informal learning experiences” (McCombs & Whisler, 1997, p. 9). This inclusiveness makes the term appropriate not just to to the field of education but also to the field of human resource development (HRD).

making it appropriate for the present research. The research hypotheses under study will delineate what the research proposes to test and the values on which they will be judged. Texas currently does not have a method to evaluate KSAs in its 2-year public colleges, making this research significant at this time. The current research seeks to identify an instrument that can be used to assess the human resource KSAs needed for faculty to successfully implement the teaching processes that will lead to a greater number of graduates, particularly among HURMs, economically disadvantaged, and academically underprepared students—populations identified in *60x30TX* as important for reaching its goals (THECB, 2015). The limitations, delimitations, and definitions sections will help convey the scope of the present research. Finally, the summary will help express how these pieces fit together to create a coherent whole.

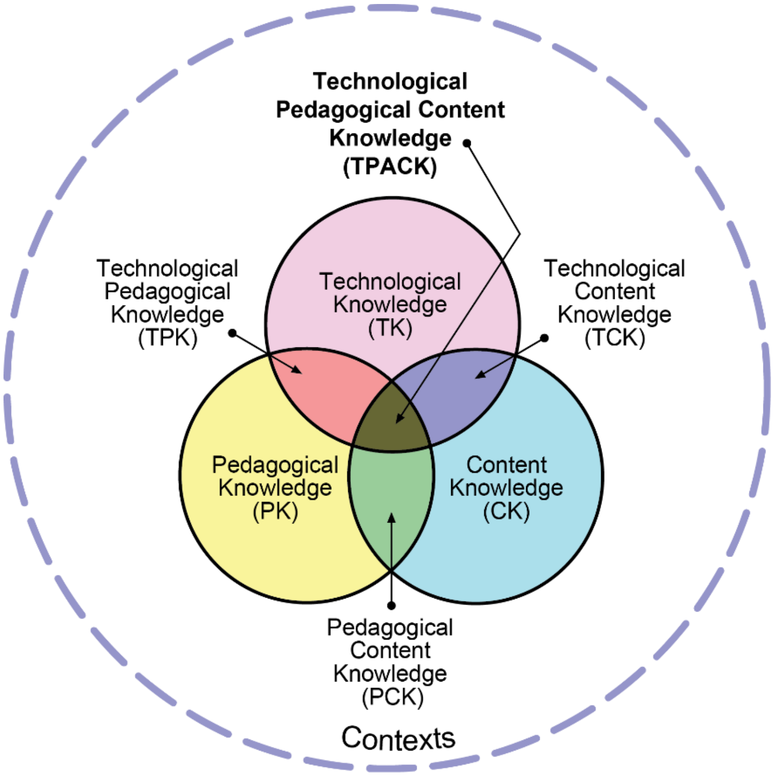

*Figure 2*. TPACK framework (tpack.org, 2012).

## Background of the Problem

Community colleges in the United States serve almost half of the undergraduate student population (National Student Clearinghouse Research Center [NSCRC], 2017; USDoE, 2010d). In open-admission institutions, students are not required to meet admission criteria such as minimum academic grade point averages or test scores (Friedel, Killacky, Katsinas, & Miller, 2014), resulting in 2-year public colleges serving a higher proportion of HURMs, economically disadvantaged students, and academically underprepared students than 4-year colleges and universities do (CCCSE, 2016; USDoE, 2010a; 2010b; 2010c; 2010d). These students are at-risk of noncompletion of degree, which often leads to fewer economic prospects for themselves and their communities (Bailey et al., 2015; Shugart, 2016). Likewise, Texas 2-year public colleges also serve a higher proportion of HURMs, disadvantaged, and underprepared students when compared to their 4-year counterparts (THECB, 2016; 2017). In 2015, the THECB created its strategic plan for higher education targeting at-risk students as important to continued economic growth, focusing on learner-centered principles (see Definitions) and technology-use strategies for learner success. Learner-centered principles, created by the American Psychological Association (APA, 1993; 1995; 1997; McCombs & Whisler, 1997), and the use of technology help all students achieve positive student outcomes but have an even greater impact on at-risk students (cf. Capar & Tarim, 2015; Shugart, 2016).

### Community College Students in the United States

Community colleges are responsible for teaching approximately one-half of all undergraduate students in the United States (Bailey et al., 2015; Shugart, 2016; USDoE, 2010d). The focus on open access and enhanced economic opportunities for students and their communities facilitates the enrollment of diverse student populations at these institutions (Friedel et al., 2014; Shugart, 2016). Two-year public colleges serve more HURMs, more economically disadvantaged students, and more academically underprepared students than their 4-year counterparts (see Table 1; Bailey et al., 2015; CCCSE, 2016; Mellow, Wollis, & Laurillard, 2011; Salinas & Garr, 2009; USDoE, 2010a, 2010b, 2010c, 2010d).

Table 1

*U.S. public higher education enrollment by institution type and race/ethnicity, Fall 2008*

| Race/ Ethnicity | All public institutions | % of Total | 4-year | % of 4-year | 2-year | % of 2-year |
|---|---|---|---|---|---|---|
| White | 8,817,677 | 65.1% | 4,879,223 | 69.6% | 3,938,454 | 60.2% |
| Black | 1,759,200 | 13.0% | 827,342 | 11.8% | 931,858 | 14.3% |
| Hispanic | 1,832,397 | 13.5% | 709,919 | 10.1% | 1,122,478 | 17.2% |
| Asian/Pacific Islander | 982,876 | 7.3% | 518,340 | 7.4% | 464,536 | 7.1% |
| American Indian/Alaska Native | 153,030 | 1.1% | 72,600 | 1.0% | 80,430 | 1.2% |
| Total Enrollment | 13,545,180 | 100.0% | 7,007,424 | 100.0% | 6,537,756 | 100.0% |

*Note*. Adapted from “Status and Trends in the Education of Racial and Ethnic Minorities. Table 24.3: Number and percentage distribution of U.S. citizen enrollment in degree-granting institutions, by race/ethnicity and institution type: 2008” by USDoE, 2010d.

The following factors contribute to lower completion rates for community college students, thereby restricting their economic opportunities (Alfassi, 2004; Bailey et al., 2015; Deksissa, Liang, Behera, & Harkness, 2014; Shugart, 2016). Economically disadvantaged students are more likely to be from HURMs (USDoE, 2010a). These minority groups have lower academic achievement in reading and mathematics throughout their K–12 experiences (USDoE, 2010b, 2010c), leading to academic unpreparedness when they reach college. Overall, community college students are academically underprepared as evidenced by the high percentage of students (60–68%) who must take developmental or remedial courses upon enrollment (Bailey et al., 2015; CCCSE, 2016; Mellow et al., 2011).

### Community College Students in Texas

In Texas, the focus and data for 2-year public colleges are similar. Texas' 50 community college districts serve more than 52% of the state's undergraduate students (THECB, 2016). Texas community colleges are open-admission institutions in contrast to their 4-year counterparts (Friedel et al., 2014; Kadden, 2009). Data from 2016 fall enrollment show that Texas 2-year public colleges educate more than 58% of the state's HURMs (THECB, 2017). While enrollment data for economically disadvantaged students is not available, in 2016 2-year public institutions awarded slightly more than half (i.e., 51.1%) of all undergraduate degrees and certificates to economically disadvantaged students (see Definitions; THECB, 2017).

The 2013 THECB data, the latest publicly available, show that more than 58% of all Texas community college students were academically underprepared in at least one area. More than 10% of Texas 2-year public college students were underprepared in all areas measured (mathematics, reading, and writing) while only 3.5% were academically prepared in all areas (THECB, 2017). In contrast, that same year (2013) more than 72% of all 4-year public university students in Texas were academically prepared in at least one area while less than 5% were academically underprepared in all areas (THECB, 2017). This academic underpreparedness leaves more Texas community college students at greater risk of noncompletion than their 4-year counterparts (THECB, 2015).

Research reveals that learner-centered teaching practices improve results for all students but particularly for HURMs, economically disadvantaged, and academically underprepared students (Alfassi, 2004; Salinas & Garr, 2009; Shugart, 2016; Strobel & van Barneveld, 2009; Wood et al., 2016). Literature on learner-centered practices highlights the role of technology in making authentic activities more accessible to faculty and students, leading to positive long-term outcomes for students both academically and economically (e.g., Bain, 2004; Darling-Hammond, Zielezinski, & Goldman, 2014; Harackiewicz & Priniski, 2018). Because the *60x30TX* plan targets HURMs, economically disadvantaged, and academically underprepared populations, and because the plan highlights learner-centered principles and technology use as strategies to achieve goals, it is critical that Texas 2-year public college faculty use learner-centered practices and incorporate technology as suggested in *60x30TX* (THECB, 2015).

## Learner-Centered Principles

In 1934, Dewey suggested that real learning occurs through iterative experience and experimentation and, most ideally, within real-world contexts (Karagiorgi & Symeou, 2005; Kolb, 1984; Shulman, 1987). Piaget (1953) asserted that individuals construct knowledge as a result of their active interactions within their environment; he further contended that individuals' developmental stages influence knowledge construction (Kolb, 1984; McCombs & Whisler, 1997). Vygotsky's (1978) social constructivist theory on the zone of proximal development proposed that individuals increase their learning capability through problem solving guided by competent adults in collaboration with more capable peers (Karagiorgi & Symeou, 2005; Kolb, 1984; Li & Lam, 2013).

In 1990, the APA appointed a Presidential Task Force on Psychology in Education to study how the psychology of education could provide guidance in designing educational systems for positive student outcomes for all learners (APA, 1993; McCombs & Whisler, 1997). As a result, the APA and Mid-continent Regional Educational Laboratory (McREL) published *Learner-Centered Psychological Principles* in 1993 with revisions in 1995 and 1997. They created this research-based document to "provide useful information consistent with research … in the areas of learning, motivation, and human development" (APA, 1993, p. 4). Building on Dewey's conception of experience as the basis of all significant learning (1938), the cognitive constructivist theory of Piaget (1953), and the social constructivism of Vygotsky (1962, 1978; Karagiorgi & Symeou, 2005; Kolb, 1984; Paris & Combs, 2000), the APA developed 12 psychological principles pertaining to both the learner and the learning environment. In 1995, the APA restructured the principles and added an additional two, leading to 14 principles. The APA made minor revisions two years later (1997). The 14 principles include cognitive and metacognitive factors, motivational and affective factors, developmental and social factors, and individual differences (APA, 1995; 1997; see Definitions).

Learner-centered principles can improve academic outcomes for at-risk students, lead to higher completion rates, and improve the economic futures of individual students as well as their communities (e.g., Alfassi, 2004; Bailey et al., 2015; Deksissa et al., 2014; Lombardi, 2007; Prince & Felder, 2006). Learner-centered teaching practices have proven to be effective across grade levels, content areas, and modalities; furthermore, they particularly benefit at-risk students (e.g., Bullock, Johnson, & Callahan, 2016; Capar & Tarim, 2015; Darling-Hammond et al., 2014, Eyyam & Yaratan, 2014; Harackwicz &

Priniski, 2017). The *60x30TX* strategic plan recognizes learner-centered principles as critical to the plan's success by highlighting their role in completion rates and workforce readiness, both of which it ties to future economic competiveness and relevancy (THECB, 2015).

Modern technology allows students to collaborate, structure data or content for meaning-making, test theories and hypotheses, discover patterns among concepts or within data, consult experts regardless of location, and creatively depict their new knowledge (e.g., Howland, Jonassen, & Marra, 2012; Jonassen, 1996; Jonassen, Peck, & Wilson, 1999). Modern technology can assist faculty in creating authentic (i.e., real-world), engaging learning activities that lead learners to discover, or construct, important knowledge for themselves using integrated learning activities to incorporate multiple concepts from a content area, from discipline-specific vocabulary and historical context to critical analyses of multiple cases (e.g., Bain, 2004; Duffy & Jonassen, 1992; Osman, Jamaludin, & Iranmanesh, 2015; Prince & Felder, 2006). Technology, then, is an ideal fit for constructivist, social constructivist, and experiential learning—the foundations of learner-centered principles (e.g., Howland, Jonassen, & Marra, 2012; Jonassen, Peck, & Wilson, 1999; Kang & Chung, 2015).

Access to information, a quintessential element of 21st-century technology, enhances inquiry and problem-based learning activities that develop cognitive learning skills, create a sense of self-efficacy in students, and boost interest in the subject (Bilgin et al., 2015; Deksissa et al., 2014; O'Banion, 1997). The incorporation of general technology as a communication, collaboration, and creative dissemination tool (Jonassen, 1996), as well as discipline-specific technologies (Mishra & Koehler, 2006), helps prepare students for increasingly technological employment, allowing them to effectively compete in the economic marketplace, as noted by the Association of American Colleges and Universities (2008) and the *60x30TX* strategic plan (Kuh & Schneider, 2008; Salinas & Garr, 2009; THECB, 2015).

The *60x30TX* plan's call to use learner-centered principles and technology to achieve its goals are reason enough to consider these needed KSAs in Texas community college faculty (2015). Technology use (e.g., Bilgin et al., 2015; Deksissa et al., 2014; Howland, Jonassen, & Marra, 2012; Jonassen, 1996; O'Banion, 1997) and learner-centered practices increase positive outcomes in all students (e.g., Bullock, Johnson, & Callahan, 2016; Capar & Tarim, 2015; Darling-Hammond et al., 2014, Eyyam & Yaratan, 2014; Harackwicz & Priniski, 2017). At-risk students, who enroll at a higher rate at community colleges (CCCSE, 2016; THECB, 2017; USDoE, 2010a; 2010b; 2010c; 2010d), benefit more positively from learner-centered practices than their peers at 4-year institutions do (e.g., Bilgin et al., 2015; Darling-Hammond et al., 2014; Wood, Harris, & White, 2015).

These factors are indirect indicators that learner-centered pedagogical knowledge and technological knowledge as measured in TPACK (TK, TCK, TPK, and TPACK) are KSAs needed in Texas community college faculty; regretfully, these KSAs are not currently measured in Texas community college faculty (SACSCOC, 2006; TEC §130). Finding an instrument that can return reliable and valid data on these constructs may help Texas community colleges and their faculty in focusing human resource development efforts to align needed KSAs with current Texas community college faculty self-assessed knowledge. The present research uses a variation of an instrument (Koh, Chai, & Tsai,

2014) designed to measure all seven constructs of TPACK through a learner-centered lens, an instrument appropriate to the KSAs and the *60x30TX* plan.

## Statement of the Problem

In the early years of public 2-year colleges in Texas, faculty were certified in both content and pedagogical knowledge, although it appears that by 1955 this ceased to be the case (Garrett, 2010). Texas currently relies upon the recommendation of each community college's president and the accreditation process to assess its faculty's KSAs (SACSCOC, 2006; TEC §130). The accreditation agency—the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC)—currently assesses 2-year public college faculty on content knowledge only by transcript evaluation (2006). Neither Texas nor SACSCOC assess community college faculty on pedagogical or technological knowledge (SACSCOC, 20167; TEC §130), making it unclear whether Texas 2-year public college faculty have the KSAs to implement the learner-centered principles needed to carry out the *60x30TX* plan.

### Community College and Faculty Evaluation Development in Texas

As early as 1840, Texas public elementary and secondary school teachers were county certified by examination. The county justices were required to guarantee the moral and academic standards (reading, writing, grammar, arithmetic, and geography) of teachers within their counties. In 1879, a first-class teaching certification examination included a section on teaching methods. By 1910, all prospective university teachers were required to demonstrate successful teaching experience or engage in a 27-week teaching practicum. Teachers became state certified by examination in 1911 (Garrett, 2010).

Texas created its first public junior colleges in the 1920s (Cross & Glover, 1985; Friedel et al., 2014). These first public junior colleges were "extensions of public high schools grade levels 13 and 14" (Friedel et al., 2014, p. 324). In 1921, Texas passed a new teacher certification law, applicable to all public school teachers. This new law required that all teaching certificates issued would be based on college studies that included a variety of content subjects as well as pedagogical instruction (Garrett, 2010). From this information, one can extrapolate that initially public junior college teachers were certified by college-level coursework in both content and pedagogy (Cross & Glover, 1985; Garrett, 2010; Friedel et al., 2014).

By 1955, all Texas public school teachers were required to attain a minimum of a bachelor's degree and complete a state-approved teacher-education program that included pedagogical practices. That same year, the State established the Texas Commission of Higher Education, in part to create a coordinated system of higher education (Friedel et al., 2014). Over time and with the enactment of a variety of laws, the junior college system slowly separated from K–12 districts (Friedel et al., 2014); however, current Texas statutes (TEC §130) still invest independent school districts with the ability to create new junior colleges (TEC §130).

In the 1980s, Texas reintroduced certification by examination after completion of a state-approved teacher-education program that focused on both content and pedagogical knowledge (Garrett, 2010). Current Texas statues allow for some alternative routes to certification, including recognition of professional certifications in career and technical education programs (TEC§21). All K–12 public school teachers, including those taking alternative routes to certification, must take examinations in content and pedagogical knowledge, regardless of area or level (TEC§21), including “knowledge and skills necessary to improve the performance of the diverse student population” (TEC§21).

### Current Community College Faculty Evaluation in Texas

Texas does not license its community college faculty in any way (TEC §130). SACSCOC, the accrediting agency for community colleges in Texas, requires that community college transfer-credit faculty hold a master’s degree and have 18 graduate credit hours in the field in which they are teaching (SACSCOC, 2006). For faculty teaching in technical or workforce programs not designed to transfer to a bachelor’s degree, a bachelor’s degree in content area or an associate degree and “demonstrated competencies,” generally meaning certificates and licenses such as one might obtain for teaching welding or auto repair, are sufficient to meet SACSCOC guidelines (2006). These faculty qualification guidelines reveal that community college faculty are assessed only on their content knowledge (SACSCOC, 2006). Neither the State of Texas nor SACSCOC examine pedagogical or technological KSAs (SACSCOC, 2006; TEC §130).

## Theoretical Framework

In 2006, Mishra and Koehler introduced their theory of technological pedagogical content knowledge, initially given the acronym TPCK, and usually referred to as the TPACK framework (see Figure 2; Thompson & Mishra, 2007). Mishra and Koehler theorized that just as PCK emerges from the intersection of CK and PK (Shulman, 1987), technological content knowledge (TCK) emerges from the intersection of TK and CK, technological pedagogical knowledge (TPK) emerges from the intersection of TK and PK, and technological pedagogical content knowledge (TPCK) emerges from the intersection of PCK, TCK, and TPK (Mishra & Koehler, 2006). In 2007, the TPCK acronym was changed to TPACK in an effort to (a) make it easier to pronounce and discuss, (b) to emphasize the necessity of having all three constructs (**T**echnology **P**edagogy **A**nd **C**ontent **K**nowledge), as well as to focus on the idea that (c) integration of all the pieces form a new whole (Thompson & Mishra, 2007). Chapter 2 provides a more detailed look at the development of TPACK theory.

Numerous professional associations have supported technology integration and TPACK theory as important to teaching practice (cf. Benton-Borghi, 2013; Graham, 2011). In 2002, the American Association of Colleges of Teacher Education (AACTE) reported that colleges of teacher education have been concentrating on preparing teachers to integrate technology into their teaching since the early 2000s (Benton-Borghi, 2013). TPACK theory has been supported by AACTE, which published the first *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators* in 2008 (Benton-Borghi, 2013; Brantley-Dias & Ertmer, 2013; Colbert, Boyd, Clark, Guan, Harris, Kelly, & Thompson, 2008). Graham (2011) reported that the American Educational Research Association (AERA) has supported TPACK by incorporating it into its Technology as an Agent of Change in Teaching and Learning special interest group since at least 2008 (AERA, 2008; 2009) and more recently with 10 TPACK sessions at conferences (AERA, 2015; 2017). The National Council for Accreditation of Teacher Education (NCATE) included technology in their professional standards in 1997 and 2008 (Benton-Borghi, 2013); similarly, the National Technology Plan by the U.S. Department of Education in 2004 and in 2010 "mandated the role of technology in teaching and learning" (Benton-Borghi, 2013, p. 246). The NCATE adopted the International Society for Technology in Education's (ISTE) national education technology standards for teachers (NET-S,2002;

Benton-Borghi, 2013). ISTE also supported TPACK by creating special interest groups and conference strands (Graham, 2011).

These well-respected professional organizations' publication and dissemination of Mishra and Koehler's (2006) theory testify to its wide acceptance as the primary theory of teaching competency in the United States today. Due to its extensive acceptance and support from professional organizations as well as its learner-centered usefulness and technology focus, Mishra and Koehler's 2006 TPACK theory of teaching competencies could inform the assessment of the KSAs for Texas 2-year public college faculty as items from the related instrument focus on a constructivist, or learner-centered, approach.

## Purpose of the Study

The purpose of the present study was to assess the construct validity of data from a constructivist-oriented self-report TPACK survey for a sample of Texas 2-year public college faculty. The instrument used in this study is the Community College TPACK Survey for Meaningful Learning (CC–TSML), a minor revision of the TPACK Survey for Meaningful Learning developed and tested by Koh, Chai, and Tsai (2014). Chapter 2 provides a comprehensive review of the TPACK survey; Chapter 3 includes a synopsis of the procedure used to revise the TPACK Survey for Meaningful Learning. An item-by-item review of the revisions to the TPACK Survey for Meaningful Learning is included in the Appendices.

## Research Hypotheses

The following hypotheses were tested in this study of the reliability and validity of data collected with the CC–TSML in Texas 2-year public college faculty using a sequential exploratory–confirmatory factor analysis approach as recommended by

Worthington and Whittaker (2006). An exploratory factor analysis was first conducted because the survey items were revised, and the instrument had never been tested with U.S. community college faculty. The CFA followed to evaluate pattern and structure coefficients, composite reliability, convergent validity, discriminant validity, and model fit. A commonality analysis was conducted to determine the amount of variance that was unique and shared among the independent variables of TPACK (CK, PK, and TK). Commonality coefficients were also derived based on correlations reported in Koh et al. (2014) and compared to the commonality coefficients (CC) derived from data collected in the present study.

### EFA Hypotheses

H1.1: Pattern coefficients will be greater than .50 with cross-loading of less than .32 (e.g., Costello & Osborne, 2005).

H1.2: Structure coefficients will load most heavily on their respective factors (Graham, Guthrie, & Thompson, 2003).

H1.3: Cronbach's alpha internal reliability coefficient values for subscales will be greater than .80 (Henson, 2001).

### CFA Hypotheses

H2.1: Pattern coefficients will be greater than .70 (cf. Hair, Black, Babin, & Anderson, 2015; Kline, 2016; Tabachnick &Fidell, 2007).

H2.2: Structure coefficients will load most heavily on their respective factors (Graham et al., 2003).

H2.3: Composite reliability (CR) for each construct will be greater than .70 (cf. Hair et al., 2015)

H.2.4: Convergent validity as measured by pattern coefficients greater than .70 (Kline, 2016) and less than .95 (cf. Bagozzi & Yi, 1988) and average variance extracted (AVE) greater than .50 (cf. Bagozzi & Yi, 1988).

H.2.5: Discriminant validity as measured by the square root of the AVE will be greater than the individual factor correlations (cf. Bagozzi & Yi, 1988; Hair et al., 2015).

H2.6: Data from the TPACK will yield good global fit indices as measured by: TLI $\geq$ .95, CFI $\geq$ .95, RMSEA $\leq$ .06, SRMR $\leq$ .05(cf. Schumacker & Lomax, 2016).

H2.7 Data from the TPACK will yield absolute value of residual correlations less than .10 (cf. Kline, 2016).

## Significance of the Study

The lack of data of Texas 2-year public college faculty KSAs makes it impossible for faculty, colleges, or the THECB to identify current strengths and opportunities for growth for the pedagogical and technological knowledge necessary for successful implementation of the *60x30TX* strategic plan. Moreover, the present researcher was unable to find any published peer-reviewed research on TPACK in U.S. community college faculty in the comprehensive literature review as detailed in Chapter 2.

Identifying potential misalignment in Texas community college faculty KSAs can highlight areas of focus for faculty development efforts that may lead to better student course- and program-level outcomes, a necessary condition for the success of *60x30TX*, particularly for historically underrepresented minority students (THECB, 2015). As stated in the THECB strategic plan: “goals for Texas higher education … cannot be postponed” (2015, p. viii); therefore, it is critical that Texas institutions quickly find a simple, easily deployed, valid, and reliable assessment of KSAs of its 2-year public college faculty. Identifying an instrument that can collect valid and reliable self-assessment data to measure pedagogical and technological knowledge and that focuses on learner-centered principles and technology integration (e.g., Mishra & Koehler, 2006) in Texas community college faculty may provide an understanding of their KSAs and their preparedness to perform their core role function—*teaching*— in support of the goals of the THECB strategic plan (TEC §130; THECB, 2015).

## Limitations

Self-report data may be inaccurate due to consistency motif bias, positive and negative affectivity, transient mood state, item social desirability, and "evidence that self-reports of behavior are often considerably different from the reports of others" (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003, p. 899).

Faculty email address lists collected from Texas community colleges through Public Information Act requests and used to invite faculty to participate in the study will not be 100% accurate, possibly leading to the unintentional exclusion of eligible participants.

Responses will be collected from faculty who agree to participate, increasing the potential for nonresponse bias (Lineback & Thompson, 2010).

## Delimitations

Content knowledge–related items of the CC–TMSL have been operationalized using generalized items rather than discipline-specific items (Shulman, 1987; Schmidt, Baran, Thompson, Mishra, Koehler, & Shin, 2009; Koh, Chai, & Tsai, 2014).

Pedagogical knowledge–related items of the CC–TMSL have been operationalized using learner-centered principles (Koh, Chai, & Tsai, 2014).

Technological knowledge–related items of the CC–TMSL have been operationalized using emerging technologies (Cox & Graham, 2009; Graham, 2011).

The study will be limited to faculty at 2-year public colleges in Texas. This study does not consider faculty outside of Texas, faculty inside Texas who teach at vocational- or technical-only colleges, private 2-year colleges, public or private universities, or for-profit institutions.

Data will be collected at one time, which may lead to common method variance and bias (Podsakoff et al., 2003; Podsakoff, MacKenzie, & Podsakoff, 2011).

Self-report data will be used for this study.

## Definition of Terms

*Academically Underprepared Students* – students who must take remedial or developmental education courses (Mellow et al., 2011).

*Community College* (CC) – a 2-year public college in the State of Texas that is regulated under TEC §130.

*Content Knowledge* (CK) – the depth and breadth of discipline knowledge and its organization (Mishra & Koehler, 2006; Shulman, 1987).

*Economically Disadvantaged Students* – students who are eligible for free or reduced-meals under the National School Lunch and Child Nutrition Program; or have, according to the TEA, other economic disadvantages, including: (a) being from a family with an annual income at or below the official federal poverty line; (b) being eligible for Temporary Assistance to Needy Families (TANF) or other public assistance; (c) having received a Pell Grant or comparable state program of need-based family assistance; (d) being eligible for programs under Title II of the Job Training Partnership Act (JTPA); or (e) being eligible for benefits under the Food Stamp Act of 1977 (TEA, 2017).

*Emerging Technology* – technologies new to the learning environment (Graham, 2011).

*Historically Underrepresented Ethnic Minorities (HURMs)* – African American, Latino, and Native American students (Salinas & Garr, 2009); in Texas, African American, Hispanic, and Other (THECB, 2017).

*Learner-Centered Practices* (also called student-centered, constructivist, and social constructivist) – include the following factors: (1) cognitive and metacognitive, (2) motivational and affective, (3) developmental and social, and (4) individual difference factors; for a more thorough discussion, see APA Board of Educational Affairs (1997). Examples of learner-centered practices include hands-on learning, scientific inquiry, formative assessment, frequent feedback, critical thinking exercises (Deksissa et al., 2014); collaborative assignments and projects, research, community-based learning, internships, and capstone projects (Kuh & Schneider, 2008); role-playing games, simulations, case studies, and virtual reality (Karagiorgi & Symeaou, 2005; Lombardi, 2007); and problem- or project-based learning, case studies, discovery learning, and just-in-time teaching (Prince & Felder, 2006), among many others.

*Non-Minority Student Groups* – White/European American and Asian American (Salinas & Garr, 2009; THECB, 2017).

*Pedagogical Knowledge* (PK) – the knowledge of teaching methodologies that promote positive student learning outcomes (Shulman, 1987) across all subject areas (Cox & Graham, 2009).

*Pedagogical Content Knowledge* (PCK) – the knowledge of teaching methods that are suitable for the content; the common misconceptions students have for the content (Mishra & Koehler, 2006; Shulman, 1987).

*Technological Knowledge* (TK) – technologies, typically digital, that are new to the learning environment and are not seen as so ubiquitous as to be invisible (e.g., books; Cox & Graham, 2009; Graham, 2011; Mishra & Koehler, 2006).

*Technological Content Knowledge* (TCK) – content-specific knowledge about which technologies can best be used to represent the content; how best to represent the content given the technologies specific to the discipline (Mishra & Koehler, 2006).

*Technological Pedagogical Knowledge* (TPK) – knowledge about technologies used for teaching and learning; methodological knowledge about how those technologies may require change in pedagogical practice (Cox & Graham, 2009; Mishra & Koehler, 2006).

*Technological Pedagogical Content Knowledge* (TPACK) – the knowledge of how best to represent teaching concepts using technology; how various pedagogical practices use technology in content-effective ways; how technology can help students master concepts within their content area; a student’s prior knowledge of the subject; and how technology can be used to build on existing knowledge (Hughes, 2005; Mishra & Koehler, 2006).

## Summary

In 2015, Texas launched *60x30TX*, a strategic plan for higher education designed to ensure the future prosperity of the state and its citizens (THECB). In order to achieve these goals, *60x30TX* supports learner-centered (e.g., constructivist) principles and effective use of technology (THECB, 2015). At present, there is no certification, examination, or research of Texas 2-year public college faculty to determine whether their KSAs are in alignment with those needed for the success of the state's strategic plan.

The present research sought to provide initial evidence of construct validity for data from CC–TSML in Texas 2-year public college faculty. Identifying an instrument that can produce reliable and valid data assessing the TPACK in Texas community college faculty may assist the state, its 2-year public colleges, and faculty-development professionals identify and target resources for maximum impact on faculty learner-centered KSAs, a necessary condition for the success of the *60x30TX* plan (THECB, 2015).

# Chapter Two – Literature Review

Mishra and Koehler's (2006) theory of teaching competencies—technological pedagogical content knowledge (TPACK)—underpins the present study that considers the construct validity of data from a constructivist-oriented self-report TPACK survey for a sample of Texas 2-year public college faculty. This chapter presents a brief history of theory leading to the development of TPACK theory, the tenets of TPACK theory, and refinements to the technology construct of TPACK theory. After reviewing the literature on theory, this chapter presents an in-depth analysis of the instruments available to measure TPACK.

The literature review for this study used ERIC, Web of Science, and PsycINFO as well as a search of the terms "TPCK," "TPACK," or "technological pedagogical knowledge" in the title of peer-reviewed journals from 2005 through December 2016 using the same process Voogt et al. used in 2012. This literature review was updated in October 2017. The Scopus database was not included either time as it was not available at the time the review was conducted. These articles formed the base of the literature review. Reading articles and reviewing their reference sections resulted in additional important items.

## Development of TPACK Theory

Shulman's (1986a; 1986b) seminal work began the task of placing a teacher's knowledge of content and knowledge of pedagogical techniques into a coherent theory of teaching competencies for effective instruction, which he termed pedagogical and content knowledge (1987), dubbed PCK by later researchers (e.g., Keating & Evans, 2001). Shulman's (1987) theory suggested content knowledge and knowledge of pedagogical practices join to create a "special amalgam" (p. 8) of pedagogical practices appropriate for the content, a concept Shulman argued differentiates a teacher from a content expert. Shulman's (1987) theory included a curricular knowledge construct as a separate although necessary skill (see Figure 3) that includes the "tools of the trade" (p. 8; e.g., effective textbook use).

Researchers such as Hughes (2005), Keating and Evans (2001), and Pierson (2001) began a conversation in the literature searching for a way to specifically integrate modern technology into Shulman's (1987) model. Later researchers (e.g., Angeli & Valanides, 2009) pointed out that Shulman's (1987) "tools of the trade" include transparent technologies (Mishra & Koehler, 2006) such as the textbooks Shulman (1987) referenced, which are a form of technology that is no longer considered "technology" (Cox & Graham, 2009).

In 2001, Keating and Evans published their grounded theory study based on interviews with 11 preservice U.S. teachers in an educational technology course using PCK theory (Shulman, 1987). The study focused not only on teachers' expertise and use of technology but also on the impact technology can have on students' conceptualizations of the content matter. When Keating and Evans postulated that

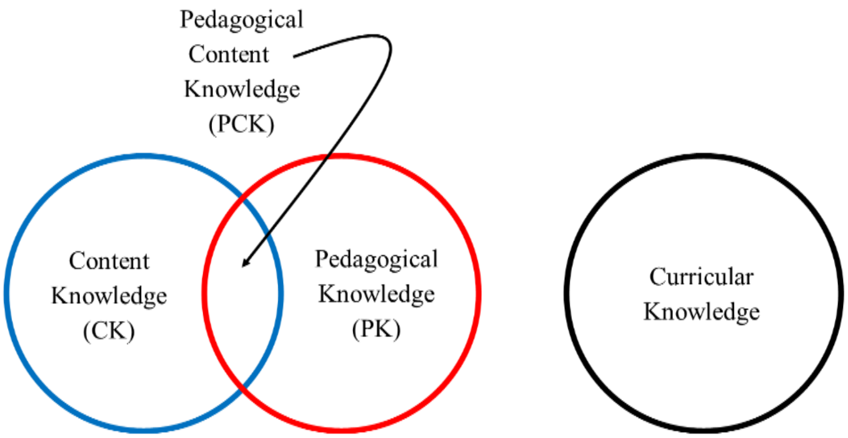

*Figure 3.* Shulman's (1987) representations of content, content pedagogical knowledge, and curricular knowledge.

technological pedagogical content knowledge is a specialized form of PCK (see Figure 4), they moved Shulman's (1987) vision of the "tools of the trade" into the confluence of content knowledge and pedagogical knowledge and extended PCK theory (Shulman, 1987) such that it specifically addressed "technology." These authors were the first to style the phrase "technological pedagogical content knowledge" and the acronym TPCK, later adopted by Mishra and Koehler (2006) for their theory of teaching competencies (Keating & Evans, 2001).

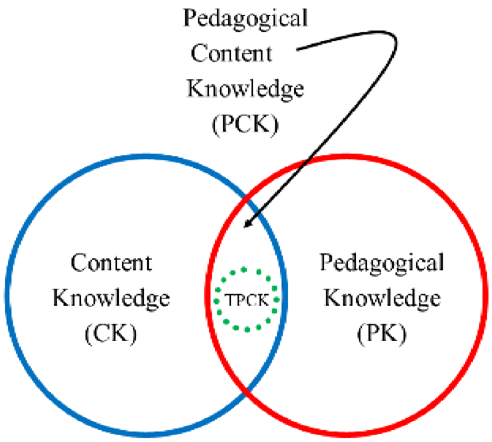

*Figure 4.* Keating and Evans' (2001) representations of content, content pedagogical knowledge, and technological pedagogical content knowledge (TPCK).

During the same year Keating and Evans (2001) published their study, Pierson (2001) published a qualitative study of in-service U.S. elementary teachers in a staff development program also using PCK theory (Shulman, 1987) as the foundation. Instead of positioning technology as a form of PCK (Keating & Evans, 2001), Pierson added a separate technology construct and suggested that technology integration is a function of teaching expertise (see Figure 5). In her four-construct theory, Pierson included three constructs from Shulman (1987): content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), and added technological knowledge (TK). The Pierson technology integration model, in contrast to Keating and Evans (2001), suggested that TPCK is a special type of new knowledge arising from the intersection of PCK and TK, rather than a specialized type of PCK knowledge. This theoretical placement of TPCK extended the ideas of Keating and Evans while honoring Shulman's theoretical arguments bringing content and pedagogical knowledge together as PCK.

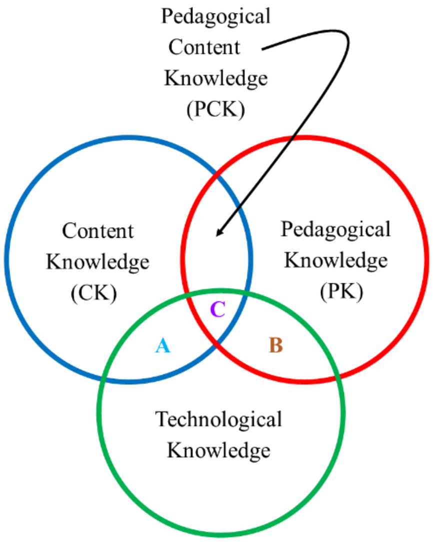

*Figure 5*. Pierson's (2001) representations of content, content pedagogical knowledge, and technological pedagogical content knowledge (TPCK). A = Intersection of CK and TK—specialized knowledge associated with content-related technology. B = Intersection of PK and TK—expertise to organize and manage learning technologies. C = Intersection of PCK and TK—complete technology integration.

In 2005, Hughes published a multiple case study of four U.S. English language arts teachers, examining the teachers' technology integration as part of a professional development program using Shulman's 1987 PCK theory to underpin her work. Hughes' study focused primarily on teacher attitudes about the value of technology and how that impacts their use of technology in supporting their own pedagogical practices. Hughes suggested that technology-supported pedagogy is a specialized form of PK separate from CK or PCK (see Figure 6). This study acknowledged Shulman's 1987 work but ignored the work of more current studies (e.g., Keating & Evans, 2001; Pierson, 2001).

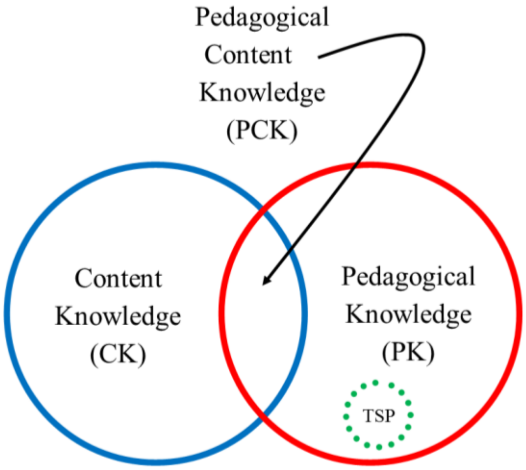

*Figure 6.* Hughes' (2005) representations of content, content pedagogical knowledge, and technology-supported pedagogy.

## TPACK Theory

In 2006, Mishra and Koehler published their theory of technological pedagogical content knowledge (TPCK). Mishra and Koehler's theory brought together Shulman's 1987 PCK theory with a reformation of Pierson's 2001 theoretical development of TPCK. Building upon Shulman's 1986 work integrating PK and CK into PCK and with the purpose of providing a theoretical grounding upon which to study the integration of technology into teaching competencies, Mishra and Koehler developed TPCK theory (renamed TPACK; Thompson & Mishra, 2007). Mishra and Koehler used five years' worth of design experiment studies conducted with U.S. teachers across levels (K–12 to university) to inform their 2006 theory. They based their theory on the idea that teaching is a complex activity that draws on knowledge from many areas, including technology and its effective use; their theory specifically addressed what constitutes technology. Shulman's (1987) conceptualization of technology was limited to "commonplace" technologies (Mishra & Koehler, 2006, p. 1023). Mishra and Koehler's view of technology incorporates "digital computers and computer software, artifacts and mechanisms that are new and not yet part of the mainstream" (p. 1023). Using this definition of technology, Mishra and Koehler extended Shulman's 1986 theory that PCK develops at the intersection of content knowledge and pedagogical knowledge by adding the technological construct (cf. Pierson, 2001). Unlike Pierson's 2001study, Mishra and Koehler's 2006 theory builds on three basic constructs—content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK). Mishra and Koehler accepted that PCK develops from CK and PK (cf. Shulman, 1987) and extended that concept by theorizing that at the intersection of CK and TK, technological content knowledge (TCK) arises; at the intersection of PK and TK, technological pedagogical knowledge develops (TPK); and where TPK, TCK, and PCK converge is where technological pedagogical content knowledge emerges (see Figure 1).

## Further Development of TPACK Theory

In 2009, Angeli and Valanides published a theoretical article examining the development of TPACK theory, offering a refinement of the theory. They pointed out that technology, while not explicitly incorporated in PCK theory by Shulman (1987), was incorporated into the theory as one of the “tools of instruction” (Angeli & Valanides, 2009, p. 158). In order for TPACK to add to the theoretical literature beyond Shulman’s 1987 PCK theory, Angeli and Valanides suggested their extension and refinement of TPACK as information and communications technology (ICT) coupled with technological pedagogical content knowledge (ICT–TPACK), which focuses on specific technologies necessary for effective teaching practice, was necessary. Information communication technology TPACK, more commonly known as ICT–TPACK theory (Angeli and Valanides, 2009) included all the constructs of TPACK theory, but restricted the concept of technology to ICT technologies, and added two knowledge constructs, that of students and of the context in which the learning takes place. While Angeli and Valanides’s article is frequently cited in TPACK literature (901 Google Scholar citations), it has not gained widespread acceptance as a replacement for Mishra and Koehler’s original 2006 conception of TPACK. However, the Angeli and Valanides conceptualization of technology as ICT technologies has been foundational in the most important branch of measurement instrumentation—those developed from the Schmidt et al. (2009) instrument (cf. Angeli and Valanides, 2009; Schmidt et al., 2009).

In part to facilitate the development of measurement instruments, Cox and Graham (2009) sought to refine the definitions of the TPACK constructs in an effort to further define the “fuzzy” boundaries (p. 60) of the factors, thereby more fully clarifying what is and is not part of each construct. Using a conceptual analysis, Cox and Graham provided elaborated definitions for each construct, giving specific examples for each. Important contributions included specifying learner-centered pedagogies in the PK construct (e.g., problem-based learning) and revisiting the definition of technology across the technology dimensions (TK, TPK, TCK, and TPACK; Cox & Graham, 2009). In their definition of technology, Cox and Graham refined the "new" technologies espoused by Mishra and Koehler (2006) as "emerging technologies" (p. 63), differentiating PCK, which includes common technologies (Shulman, 1987; Mishra & Koehler, 2006), from TPACK; however, they did not limit them to ICT technologies as Angeli &Valanides (2009) had. By specifying emerging technologies in their definition of technology, Cox and Graham argued that this allows the definition of technology to shift over time, preventing the TPACK theory from becoming obsolete as technology changes. Interestingly, Cox and Graham did not provide a definition of what "emerging technology" actually means (2009). The Cox and Graham 2009 study suggested that measurement instruments will need to evolve as some technologies become commonplace, others die out, and still more emerge.

In 2011, Graham revisited the "fuzzy" (Cox & Graham, 2009, p. 60) boundary issues within TPACK. Citing the definition of technology, an issue Cox and Graham (2009) side-stepped, as critical for distinguishing PCK from the technological dimensions of TPACK, Graham reiterated the need for researchers to distinguish between "transparent technologies" and "emerging technologies" (2011; p. 1956). Cox defined emerging technologies as "new technologies (typically digital technologies) that are being investigated or introduced into a learning environment" (2011; p. 1956). He suggested this is one reason some measurement instruments (e.g., Archambault & Barnett, 2010) failed to extract all the expected factors of TPACK in factorial analyses (Graham, 2011).

## Development of TPACK Surveys

This portion of the literature review will examine the earliest attempts at measuring TPACK using survey methodology, influential survey instruments, and results of major studies specifically focused on factor analytics and SEMS studies, as well as studies in U.S. college and university faculty.

### Earliest TPACK Surveys

The earliest survey of technological pedagogical content knowledge in the published, peer-reviewed literature was conducted in the United States by Koehler and Mishra in 2005 shortly before their TPACK (at the time called "TPCK") theory was published (Mishra & Koehler, 2006). The 2005 study provided a brief introduction to their theory and its overlapping Venn diagram model. In this study, Koehler and Mishra created a course-specific survey designed to measure participant learning in one of their U.S. learning-by-design courses and to provide empirical evidence of their theory. They attempted to measure their students' perceptions of the learning-by-design approach and changes in their students' thinking in relation to various aspects of online education over time. They surveyed a small sample of 17 participants, including both instructors teaching the course and students participating in the course. Students took an online survey four times in the semester. The survey had 35 questions with 33 items using a 7-point Likert scale and two short-answer questions. Five items comprised the "Time and Effort" questions, including items such as "Overall, I have been working very hard in this course"; four items addressed "Learning and Enjoyment," including "I am enjoying my experience in this course"; and six items focused on "Group Functioning," including "Our group is getting a lot of work done." They conducted matched-pairs *t* tests;

however, only two of the survey response datasets were used, as one dataset was lost to a computer virus. The analysis of their results showed very large effect sizes (Cohen's *d* = .93) and indicated that, over time, participants found themselves working harder and engaging in more collaboration. While this first effort to measure TPACK found some very large effects of the learning-by-design process, it did not actually measure the seven TPACK constructs.

The next published effort to measure TPACK came from Archambault and Crippen (2006). They used survey design to assess 34 virtual charter school K–12 teachers in Nevada on self-assessment of preparedness in three areas of expertise: online pedagogy, course design, and technical assistance. The 11-item survey used 4-point Likert scale responses ranging from 1 = *Not at all prepared* to 4 = *Very well prepared.* Items from the survey included "Create an online environment which allows students to build new knowledge and skills" (online pedagogy), "Moderate online interactivity among students" (course design), and "Assist students with troubleshooting technical problems with their personal computers" (technical assistance). Results from the Archambault and Crippen study indicated that most of the teachers in their sample believed they were "not at all prepared" or only "somewhat prepared." Though an interesting study on faculty self-perception of preparedness for online teaching, this survey was not designed to measure the TPACK constructs published by Mishra and Koehler in 2006.

Archambault and Crippen followed up with a 2009 survey designed using TPACK theory in a nonrandom purposeful sample of K–12 online faculty that generated 596 responses from 25 U.S. states. This 24-item survey used a 5-point Likert scale (1 =

Poor, 5 = Excellent) that allowed teachers to self-assess their knowledge in all seven domains of TPACK. Items included “My ability to adjust teaching methodology based on student performance/feedback” (PK), “My ability to troubleshoot technical problems associated with hardware (e.g., network connections)” (TK), “My ability to create materials that map to specific district/state standards” (CK), “My ability to implement district curriculum in an online environment” (TCK), “My ability to anticipate likely student misconceptions within a particular topic” (PCK), “My ability to moderate online interactivity among students” (TPK), and “My ability to meet the overall demands of online teaching” (TPCK). This 2009 Archambault and Crippen study reported coefficient alphas for all seven domains of TPACK ranging from .699 (TCK) to .888 (TK). Their analysis of the data included means, standard deviations, and correlations. The correlation table showed significant and positive relationships among all constructs ranging from a low of .278 between PCK and TK to a high of .782 between PCK and PK. Their analyses showed that online K–12 faculty in the United States felt most confident in their knowledge in content, pedagogy, and pedagogical content knowledge and less sure of their knowledge in the technology domains.

Graham, Burgoyne, Cantrell, Smith, St. Clair, and Harris (2009) published the first study focused on a specific discipline: science; however, the study attempted to measure only the technology dimensions of TPACK, that is, TK, TPK, TCK, and TPACK. Their 31-item self-assessment of teacher confidence was given to 15 U.S. participants in a pretest-posttest design during their participation in a professional development program. Responses used a 6-point Likert scale (1 = *Not confident at all,* 6 = *Completely confident).* Survey items included “Use digital technologies to facilitate scientific inquiry in the classroom" (TPACK), "Use digital technologies to motivate learners" (TPK), "Use digital technologies that allow scientists to record data that would otherwise be difficult to gather" (TCK), and "Send an email with an attachment" (TK). They combined pre- and posttest data to generate coefficient alphas for the four technology constructs ranging from a low of .913 (TCK) to a high of .971 (TPK). They reported means and standard deviations for pre- and posttest data and the mean change between pretest and posttest means, as well as conducting a paired-samples *t* test and effect sizes. Graham et al. showed statistically significant positive changes in participants' technology dimensions of TPACK ranging from moderate (*d* = .5) to large (*d* = .8) effect sizes in all constructs measured.

## Most Influential TPACK Survey Instruments

In 2009, Schmidt, Baran, Thompson, Mishra, Koehler, and Shin published their study of a TPACK self-assessment instrument for U.S. preservice PK–6 teachers that included a study of internal reliability and factor analysis. In their work to develop this instrument, they reviewed other instruments that measure technology skills, teacher beliefs and attitudes, and other technology-related factors (see Table 1 in Schmidt et al., 2009, p. 126 for more detail). Schmidt et al.'s stated goal in developing this instrument is to "measure preservice teachers' self-assessments of the TPACK domains, not their attitudes about TPACK" (2009, p. 128). Using experts, they generated a 75-item instrument measured on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), which they tested with 124 U.S. preservice teachers in an instructional technology course in the United States. The CK items were divided into four areas (mathematics, social studies, science, and literacy) as these are content areas in which PK–6 teachers are expected to have expertise. Because their sample was too small to conduct a factor analysis on the entire instrument, they "investigated the construct validity for each knowledge domain subscale using principle components factor analysis with varimax rotation within each knowledge domain and Kaiser normalization" (p. 130). The factor loadings associated with these subscale factor analyses allowed them to identify items with low loadings and subsequently eliminate a total of 28 items. After removing those 28 items, they ran the subscale factor analyses again and reported factor loadings for the remaining 47 items. Coefficient alphas using the 47 items were reported for all seven domains (including four for CK items) ranging from .75 (CK–Literacy) to .92 (TPACK). The correlations among the subscales ranged from .02 (CK–Social Studies and CK–Mathematics) to .71 (TPK and TPACK). Correlations among subscales were significant at the .001 level with the exception of CK–Social Studies at the .05 level. TPACK correlated most highly with TPK (.71), TCK (.49) and PCK (.49; see Table 9 in Schmidt et al., 2009, p. 136 for detail). The 2009 Schmidt et al. survey is the most influential in the TPACK survey literature; in fact, their instrument is considered the "grandmother" of 65 of the survey instruments identified through the empirical literature review, as 49.62% of all TPACK survey instrument lineages begin with this study.

Chai, Koh, and Tsai (2010) developed their survey instrument by adapting the Schmidt et al. 2009 survey. They changed the scale anchors from a 5-point Likert scale to a 7-point scale. They also changed the CK items to reflect the cultural context (Singapore) where teachers are assigned to teach two subjects, often referred to as Curriculum Subject 1 (CS1) and Curriculum Subject 2 (CS2). In this study, Chai, Koh, and Tsai tested on items related to the basic constructs of TPACK (CK, PK, TK, and

TPACK). Their 18-item survey anchors ranged from 1 = Strongly disagree to 7 = Strongly agree. Chai, Koh, and Tsai tested their instrument with preservice Singaporean secondary school teachers taking an ICT course using a precourse ($n$ = 439)/postcourse ($n$ = 365) survey methodology. Generally good internal reliability was found in both the precourse and postcourse coefficient alphas ranging from TK = .85 to CK = .99 (precourse) and TK = .85 to TPACK = .94 (postcourse). The EFA found four distinct factors in both pre- and postcourse analyses. No items were removed from the analysis. Factor loadings ranged from a low of .64 for item "PK5 – I know how to organize and maintain classroom management" to a high of .96 for the item "TPACK2 – I can teach lessons that appropriately combine my CS1, technologies and teaching." CFA provided satisfactory model fit for the 4-factor model in both precourse and postcourse data.

Independent samples $t$ tests indicated statistically significant ($p < .001$) positive results across all basic constructs. Effect sizes indicated moderate effects (Cohen's $d$ = .61 - .69) across CK, PK, TK, and TPACK. Correlations indicated statistically significant positive correlations ($p < .01$) between TPACK and CK, PK, and TK both pre- and postcourse survey. Precourse and postcourse, the highest correlation was between TPACK and PK (precourse = .70, postcourse = .82). Step-wise regression indicated that PK had the greatest influence on TPACK, and that precourse CK, PK, and TK accounted for 54% of the variance, while postcourse it accounted for 74% of the variance. Though measuring only the basic constructs of TPACK (CK, PK, TK, and TPACK), the Chai, Koh, and Tsai (2010) survey is found in the survey lineages of 18 other studies, or 13.74% of the studies found in the empirical literature review.

Chai, Koh, and Tsai expanded on their 2010 research (Chai, Koh, & Tsai, 2010; Koh, Chai, & Tsai, 2010) with a 2011 study of 214 Singaporean preservice teachers taking an ICT course. In the 2011 study, they included all seven constructs of TPACK as measured by a 36-item survey. Several items were revised from the Chai, Koh, and Tsai (2010) instrument to focus on student-centered learning practices such as item TPK5 “I am able to facilitate my students to collaborate with each other using technology.” A sequential EFA–CFA was used to analyze the data. During EFA, two items were eliminated for low factor loadings and cross-loadings. EFA extracted eight factors as expected. The CK items were divided into first and second teaching areas as appropriate for the cultural context. Internal reliability for each subscale was demonstrated with coefficient alphas ranging from .84 (CK–CS1) to .94 (TPACK). Correlations among the factors was statistically significant ($p < .01$) and positive among all factors with the exception of TK and PCK (.12). Correlations were highest between TCK and TPACK ($r = .77$), TPK and TPACK ($r = .68$), and TPK and TCK ($r = .60$). CFA demonstrated satisfactory fit with the 8-factor model. This study represented the first time in the survey literature that all the expected factors of TPACK were successfully extracted in the EFA process. With a survey lineage reaching back to Schmidt et al. (2009), acceptable factor loadings for 34 items measuring all seven TPACK constructs and demonstrating good model fit in CFA, the Chai, Koh, and Tsai (2011) instrument can be found in the lineages of 17 further studies (12.98%) identified in the survey literature review for the present study.

The 2011 study conducted by Sahin in Turkey used an entirely new survey instrument based on Mishra and Koehler’s (2006) conceptualization of TPACK. Sahin engaged in a rigorous development process that consisted of item pool development, testing of validity and reliability, discriminant validity testing, test-retest reliability, and a translation study (translated into English). Sahin’s 47-item self-assessment instrument of teacher knowledge in all seven TPACK domains was measured on a 5-point Likert scale ranging from 1 = Not at all to 5 = Complete. Some items included “Using an electronic spreadsheet program (ex., MS Excel)” and “Using scanner” to measure TK knowledge, “Making connections between my content area and other related courses,” measuring PCK. Sahin tested the instrument with 348 preservice teachers in Turkey. EFA showed items loaded on seven expected factors with loadings for the 47 items ranging from .60 to .90. The correlation coefficients between subscales showed statistically significant ($p < .01$) and positive relationships between all subscales. The highest correlations were between PK and PCK ($r = .80$), TPK and TCK ($r = .79$), and PCK and TPACK ($r = .79$). This 2011 Sahin survey is in the survey lineage of nine other instruments representing 6.87% of the 131 surveys evaluated in the present research.

In 2012, Yurdakul, Odabasi, Kilicer, Coklar, Birinci, and Kurt developed a wholly new survey to measure TPACK using multiple expert committees to first determine teacher competencies necessary to achieve TPACK, generate a pool of items, and then verify the items. The initial expert committee determined the six competencies necessary for teachers: designing instruction, implementing instruction, innovativeness, ethical awareness, problem solving, and field specialization. Therefore, their items are aligned to these constructs rather than the seven constructs in the 2006 Mishra and Koehler theory. The second expert committee generated 38 items while a third expert committee narrowed those down to 36 items. Items were measured on a 5-point Likert scale ranging from “I can easily do it” to “I certainly can’t do it.” Sample items included “Conducting needs analysis regarding the technologies to be used in the teaching process” (designing instruction), “Using technology to motivate students in the teaching-learning process” (implementing instruction), “Using technology in updating the knowledge and skills regarding the process of measurement and evaluation” (innovativeness), “Paying attention to copy-right issues regarding digital sources used while designing instructional materials” (ethical awareness), “Solving the basic problems with technological tools used in the teaching process” (problem solving), and “Guiding colleagues regarding the use of technology to solve the problems experienced in the process of presenting content” (field specialization). The survey instrument was called the TPACK–Deep scale. Data was gathered from 995 preservice teachers attending education courses in higher education institutions in Turkey. The data were split into EFA ($n$ = 497) and CFA ($n$ = 498). During EFA, three items failed to load adequately and were removed. Four factors emerged from the EFA and were designated design, exertion, ethics, and proficiency. Internal reliability for the four factors was determined by coefficient alphas ranging from .85 (proficiency) to .92 (design). Fit indices from the CFA confirmed the 4-factor model was the best-fitting model ($\chi 2/df$ = 3.981, RMSEA = .078, SRMR = .048, GFI = .94, AGFI = .89, NFI = .91, NNFI = .94, CFI = .95). This scale was a significantly different conceptualization of TPACK from that usually found in the literature and is not appropriate for the present study. However, the Yurdakul et al. 2012 survey is the basis of 11 surveys in the literature, accounting for 8.4% of the surveys reviewed for the present study; consequently, this stream of research and the survey instruments it has created cannot be ignored.

## Factor Analytic Studies

The first EFA analysis was conducted in Schmidt and colleagues' (2009) study; however, it lacked appropriate sample size to conduct an EFA on the entire instrument, leading them to conduct an EFA on each subscale. Other attempts at instrument development (e.g., Archambault & Barnett, 2010; Chai, Koh, Ho, & Tsai, 2012; Lee & Tsai, 2010) highlighted needs for better construct definition (cf. Graham, 2011).

**Unsuccessful attempts at factor analysis.** In 2010, Archambault and Barnett conducted a study of a 24-item scale of 596 U.S. online teachers but were unable to extract all seven factors of TPACK. In this study, TK items loaded on their own factor; however, CK and PK items loaded together and TCK and TPK items loaded together (Archambault & Barnett, 2010). Koh, Chai, and Tsai (2010) conducted a study of an instrument using 1,185 preservice Singaporean teachers but their instrument failed to extract all seven factors. They were able to get TK and CK items to load on their own factors; however, PK and some PCK items loaded together on a factor the authors called Knowledge of Pedagogy; all TCK, most TPK, and all TPACK items loaded together on a factor they called Knowledge of Teaching with Technology (Koh, Chai, & Tsai, 2010).

Lee and Tsai (2010) found a 5-factor model in their EFA–CFA study conducted with 558 in-service K–12 teachers in Taiwan using an instrument focused on web technologies. In factor analysis, they were able to retain 30 items that loaded on factors they called Web–General, Web–Communicative, Web–Content Knowledge, Web–Pedagogical–Content Knowledge, and Attitudes toward Web-Based Instruction (Lee & Tsai, 2010). A 2012 study by Chai, Koh, Ho, and Tsai using a pretest (*n* = 668)-posttest (*n* = 628) research design extracted five factors (CK, PK, TK, TPK, TPACK). They found that some TPACK, PCK, and TCK items loaded together on the TPACK factor in their remaining 34 items using data from preservice teachers in Singapore (Chai, Koh, Ho, & Tsai, 2012). These studies helped highlight the need to clearly define TPACK constructs in item development (cf. Cox & Graham, 2009; Graham, 2011).

Lux, Bangert, and Whittier (2012) developed a 45-item survey and tested it with 120 U.S. preservice elementary and secondary teachers. Low factor loadings required them to remove a number of items leaving them with only 27 retained items, but they still were unable to extract all seven TPACK factors (Lux et al., 2012). Given their sample-to-item ratio was so low (2.67:1), it is impossible to tell whether they would have achieved better results with an adequate sample (Hair et al., 2015; Lux et al., 2012). Some more recent studies that attempt to develop new instruments to measure all seven factors of TPACK but fail to extract the expected factors also suffer from low sample-to-item ratios (cf. Shinas, Yilmaz-Ozden, Mouza, Karchmer-Klein, & Gluting, 2013; Valtonen, Sointu, Kukkonen, Kontkanen, Lambert, & Makitalo-Siegl, 2017).

Several other studies originating in Taiwan (e.g., Chuang, Weng, & Huang, 2015; Jang & Chang, 2016; Jang & Tsai, 2013; Liang, 2015; Liang, Chai, Koh, Yang, & Tsai, 2013) have attempted to create surveys and extract all seven TPACK factors but have been unsuccessful in doing so. An examination of survey lineages points out that one problem may be that many of these studies have attempted to build on surveys that themselves failed to extract all expected TPACK factors (cf. Liang, 2015, Jang & Chang, 2016).

**Successful Attempts.** Chai, Koh, and Tsai (2010) were successful in extracting the four basic factors of TPACK (CK, PK, TK, and TPACK), the only factors they attempted to study, in their sequential EFA–CFA study of an 18-item scale with 889 Taiwanese preservice secondary teachers. Chai, Koh, Tsai, and Tan (2011) conducted a pretest (*n* = 375)-posttest (*n* = 343) study with preservice Singaporean teachers using a 46-item survey focusing on Web 2.0 technologies and the basic constructs of TPACK, successfully extracting their expected four factors. Two other studies of basic TPACK factors (cf. Reyes, Reading, Rizk, Gregory, & Doyle, 2016; Zelkowski, Gleason, Cox, & Bismarck, 2013) in discipline-specific areas (e.g., math, science) successfully extracted the basic factors despite low sample-to-item ratios, indicating that these constructs within a specific context may now be well developed theoretically and empirically (cf. Graham, 2011; Mishra & Koehler, 2006).

Chai, Koh, and Tsai (2011) were the first to test a nondiscipline survey and successfully extract all seven factors of TPACK as postulated by Mishra and Koehler (2006). The authors used what they had learned in their successful basic factors study (Chai, Koh, & Tsai, 2010) and their unsuccessful 7-factor study (Koh, Chai, & Tsai, 2010) to build a better instrument (Chai, Koh, & Tsai, 2011). They conducted a sequential EFA–CFA on the data gathered from 214 preservice Singaporean primary and secondary teachers (Chai, Koh, & Tsai, 2011). With 34 retained items, high internal reliability coefficients (.86–.94), and good fit statistics for the 7-factor model, this survey is in the survey lineages of 17 other studies. Sahin (2011); Kaya, Kaya, and Emre (2013); and Baser, Kopcha, and Ozden (2016) all developed unique TPACK instruments that produced reliable and valid data, extracting all seven factors of TPACK in Turkish samples. Sahin’s (2011) instrument is a generalized instrument while Kaya et al. (2013) translated the 2009 Schmidt et al. instrument into Turkish. Baser et al. (2016) created a discipline-specific instrument for English as a Foreign Language (EFL) teachers. A number of research studies using previously validated instruments with only minor changes, if any, used an a priori factor structure and CFA as the basis of their analyses (e.g., Celik, Sahin, & Akturk, 2015; Pamuk, Ergun, Cakir, Yilmaz, & Ayas, 2015; Su, Huang, Zhou, & Chang, 2017).

Deng, Chai, So, Qian, and Chen (2017) created a 24-item chemistry-specific TPACK instrument based on Chai, Koh, and Tsai (2011), testing it with 280 Chinese preservice teachers. They successfully extracted all seven TPACK factors in their sequential EFA–CFA. Other researchers have successfully conducted EFA or CFA in disciplines such as Chinese language (Chai, Chin, Koh, & Tan, 2013), EFL (Baser, Kopcha, & Ozden, 2016; Hsu, 2016), geography (Su, Huang, Zhou, & Chang, 2017), science (Lin, Tsai, Chai, & Lee, 2013), and social science (Akman & Guven, 2015).

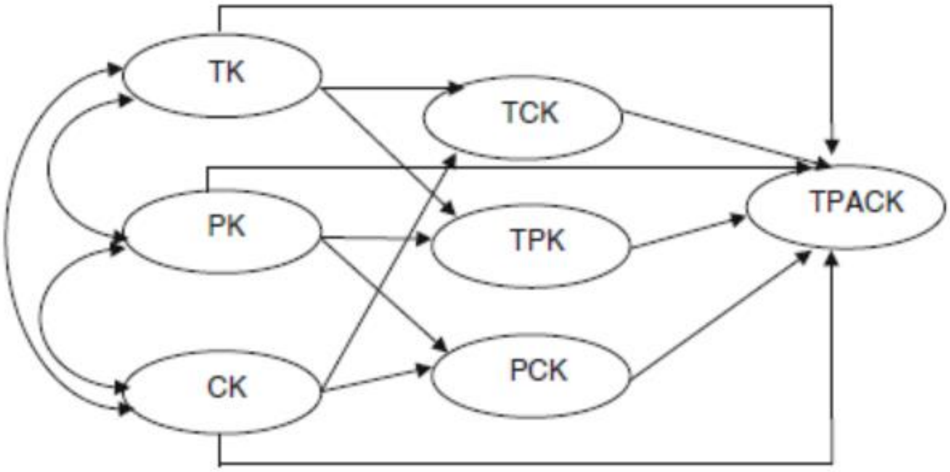

*Figure 7.* Structural model based on TPACK theory of Mishra and Koehler (2006; Koh et al., 2013).

**SEM Studies.** The structural model hypothesized by TPACK theory (Mishra & Koehler, 2006) is shown in Figure 7. Four SEM studies were examined; their structural path coefficients can be found in Table 2. Chai, Koh, Tsai, and Tan (2011) reported a structure equation model of the 5-factor model they found through their CFA using an instrument based on Schmidt et al. (2009); however, their factor structure did not reflect the expected 7-factor structure of TPACK. Their structure equation model coefficients precourse and postcourse showed fluctuations; however, they did find in both models that TK showed positive and significant effects on TPACK and TPK, PK showed positive and significant effects on TPK, and that TPK showed positive and significant effects on TPACK.

Table 2

*SEM path coefficients from SEM studies of TPACK instruments*

| | Precourse | Postcourse | | Preservice | In-Service | |
|---|---|---|---|---|---|---|
| SEM Path | Chai, Koh, Tsai, & Tan, 2011 | | Koh, Chai, & Tsai, 2013 | Dong et al., 2015 | | Celik et al., 2014 |
| CK → PCK | | | 0.34 | NS | 0.47 | 0.20 |
| CK → TCK | | | 0.25 | 0.13 | 0.14 | 0.19 |
| CK → TPACK | NS | 0.05 | NS | 0.10 | NS | NS |
| PK → PCK | | | 0.20 | 0.64 | 0.26 | 0.68 |
| PK → TCK* | | | | | | 0.40 |
| PK → TPK | 0.47 | 0.80 | 0.18 | 0.46 | 0.24 | 0.60 |
| PK → TPACK | 0.24 | NS | 0.16 | NS | NS | 0.53 |
| TK → TCK | | | 0.59 | 0.63 | 0.72 | 0.33 |
| TK → TPK | 0.16 | 0.12 | 0.68 | 0.46 | 0.66 | 0.27 |
| TK → TPACK | 0.22 | 0.62 | 0.16 | NS | NS | NS |
| PCK → TPACK | | | NS | NS | NS | 0.23 |
| TCK → TPACK | | | 0.41 | 0.49 | 0.46 | 0.53 |
| TPK → TPACK | 0.65 | 0.79 | 0.30 | 0.31 | 0.30 | |

*Not a path recognized in most TPACK literature. NS = not significant.

Koh, Chai, and Tsai (2013) conducted a CFA with a structure equation model using a sample of 455 in-service primary, secondary, and junior college teachers in Singapore using an adaptation of the Chai, Koh, and Tsai (2011) instrument. Their correlation table showed that all factors of TPACK were positive and significant ($p < .01$)

coefficients with each other (Koh, Chai, & Tsai, 2013). The structure equation model from the Koh, Chai, and Tsai (2013) study showed the strongest statistically significant and positive effects from TK to TPK (.69, $p < .0001$) and from TK to TCK (.59, $p < .0001$), and no statistically significant effects from CK to TPACK and from PCK to TPACK.

Dong, Chai, Sang, Koh, and Tsai (2015) used an instrument based on Chai, Koh, and Tsai (2011) with a sample of 390 preservice and 394 in-service teachers in China. They found statistically significant and positive correlations among all TPACK constructs for both preservice and in-service teachers. In preservice teachers, the strongest positive effects were found from TK to TCK (.63, $p < .001$), PK to PCK (.64, $p < .001$), TCK to TPACK (.49, $p < .001$), and TK to TPK (.46, $p < .001$; Dong et al., 2015). They found paths TK to TPACK, CK to PCK, PCK to TPACK, and PK to TPACK insignificant (Dong et al., 2015). Paths found to be insignificant for in-service teachers included CK to TPACK, TK to TPACK, PK to TPACK, and PCK to TPACK; however, they did find statistically significant and positive effects from TK to TCK (.72, $p < .001$), TK to TPK (.66, $p < .001$), and TCK to TPACK (.46, $p < .001$; Dong et al., 2015).

Celik, Sahin, and Akturk (2015) tested Sahin's (2011) survey in a sample of 744 preservice teachers in Turkey. While they reported "all pairwise correlations among exogenous variables are significant" (Celik et al., 2015, p. 9), they provided no table. In the structural model reported by Celik et al. (2015), they reported the most significant positive effects from PK to PCK (.684, $p < .01$), PK to TPK (.595, $p < .001$), PK to

TPACK (.534, $p < .01$), and from TCK to TPACK (.529, $p < .01$). TK to TPACK and CK to TPACK were not significant.

SEM studies of TPACK instruments alone found many consistencies with positive and significant effects for some paths (e.g., PK to TPK, TK to TPK); however, other paths show mixed results (see Table 2), pointing to a need to conduct more studies. Moreover, none of the SEM models used a sample of U.S. faculty at any level.

**College and University Faculty.** Only six published TPACK studies use either junior college or university faculty in their samples. Koh, Chai, and Tsai (2013) used junior college faculty in their sample of 455 but did not provide any indication of how many junior college faculty were in their sample. Their subject-to-item ratio was good (15:1), which allowed them to conduct CFA and SEM studies with their samples as reported above. Other studies suffered from low sample-to-item ratios from a low of 1.83:1 (Chukwuemeka & Iscioglu, 2016) using university professors of education in Cyprus to a high of 4.06:1 (Rienties, Brouwer, & Lygo-Baker, 2013). These studies did not allow for factor analysis due to low sample size. Jang and Chang (2016) had a small sample-to-item ratio (7:1) but it was sufficient to conduct an EFA; however, they were unable to extract all seven factors of TPACK, perhaps due to insufficient sample size. None of these studies used U.S. college or university faculty.

A search of ProQuest dissertations in the last 10 years using “TPACK” and “faculty” or “technological pedagogical content knowledge” and “faculty” produced four dissertations using TPACK and college or university faculty (Garrett, 2014; Hamilton, 2013; Knolton, 2014; Lavadia, 2017). All four of the dissertation studies used a modified instrument of some type with Hamilton, Knolton, and Lavadia using Schmidt et al.

(2009) as a base. Only Garrett used another instrument as base (cf. Lux et al., 2011). Most studies attempted to measure all seven TPACK dimensions (Garrett, 2014; Knolton, 2014; Lavandia, 2017) with Hamilton opting to measure only the technology dimensions of TPACK in his sample. Sample-to-item ratios were extremely small for Garrett (2014; 4.44 to 1), Knolton (2014; 0.75 to 1), and Lavadia (2017; 0.725 to 1). Only Hamilton achieved a reasonable sample-to-item ratio of 11.19 to 1 (cf. Hair et al., 2015).

Because Hamilton (2013) used a 31-item Schmidt et al. (2009) revised instrument to measure the technology dimensions of TPACK (TK, TPK, TCK, and TPACK) in a study of 347 university faculty, she demonstrated internal reliability with coefficient alphas ranging from .769 for TCK and .887 for TK (Hamilton, 2013). Hamilton conducted an EFA and found four factors, as expected (2013). She did have four items that showed significant cross-loading (> .32; Kline, 2016) but did not remove the items and re-run the EFA. Hamilton's research design included individual multiple regression studies for each of the T-dimensions of TPACK to determine whether age, academic rank, or gender influenced faculty TPACK. She found a statistically significant negative relationship between age and TK but no other statistically significant relationships for age, gender, or academic rank in relation to TK, TCK, TPK, or TPACK.

In Knolton (2014) and Lavadia (2017), researchers used a modified Schmidt et al. (2009) instrument; however, it is unclear why the researchers chose this path. While there were no widely accepted instruments from a higher education perspective, there are a number of better developed generalized instruments that could have been deployed in Knolton's study (cf. Chai, Koh, &Tsai, 2011; Sahin, 2011; Yurdakul et al., 2012). Lavadia studied science faculty and claimed there were no science specific instruments for science; however, three science-specific TPACK instruments (cf. Graham et al., 2009; Habowski & Mouza; 2014; Lin, Tsai, Chai, & Lee, 2013) were available, including Graham et al. (2009), one of the more influential survey instruments found in survey lineages. Knolton's mixed-methods study using independent sample *t* tests and open-ended questions found a statistically significant difference between faculty who rate themselves more confidently in their PK and their appropriate choices of technology. Interestingly, faculty who rated themselves as lower in PK at 86% had never completed an educational technology course (Knolton, 2014). Lavadia also used a mixed-methods design using a survey with both Likert-type responses and open-ended questions to determine that TK was the best predictor of technology adoption in instruction for science university faculty.

Garrett (2014) based her study on the Lux et al. (2011) instrument, an instrument that was unable to extract the expected TPACK factors and a study that used a low sample-to-item ratio (4.44:1). It is unclear why Garrett would have chosen that instrument considering the many generalized TPACK instruments that have successfully extracted all seven factors (e.g., Chai, Koh, &Tsai, 2011; Koh, Chai, & Tsai, 2013; Sahin, 2011). Garrett found a statistically significant difference between tenured faculty and nontenured faculty in the areas of CK, PK, PCK, and TPACK with tenured faculty feeling more confident in each of the areas.

## Research Instrument for the Present Study

To locate an appropriate survey instrument to study the seven factors of technological pedagogical content knowledge (TPACK; Mishra & Koehler, 2006) in Texas community college faculty, this researcher followed the literature search strategy of Voogt, Fisser, Pareja Roblin, Tondeur, and van Braak (2012) from their comprehensive review of TPACK theory development, instrument development, and teacher TPACK development literature. Voogt et al. used the Education Resources Information Center (ERIC), Web of Science, Scopus, and PsycINFO databases, limiting searches to the period 2005–September 2011. They searched for peer-review articles using the search terms “TPCK,” “TPACK,” and “technological pedagogical content knowledge” (Voogt et al., 2012). They initially identified 243 articles and reviewed them to determine whether they contributed to instrument development, theory development, or preservice or in-service teacher’s TPACK development (Voogt et al., 2012). Fifty-five studies were included in the Voogt et al. final literature review.

The literature review for the present study followed Voogt et al.’s (2012) search process using the same databases except Scopus, which was not available to this researcher. Search terms included “technological pedagogical content knowledge,” “TPCK,” and “TPACK” in the title of the articles (cf. Voogt et al., 2012). Limiters were included to restrict results to peer-reviewed journals in English during the period of October 2011 to September 2017, beginning where the Voogt et al. 2012 search ended.

The initial search of ERIC, Web of Science, and PsycINFO returned 509 articles. The search results were downloaded into spreadsheets, merged, and searched for duplicates. Two hundred-fifty duplicate entries were removed, leaving 259 articles for review. Abstracts and methodology sections for articles were reviewed and classified by type. Articles were inspected with survey instruments to determine the survey’s lineage. Survey lineages were compared to the search results with studies omitted from the initial search due to limiters (e.g., date, type of publication) to the spreadsheet and acquired copies of the articles. After adding the 55 studies identified by Voogt et al. (2012), a total of 329 studies were subject to further review.

In searching for an instrument to measure self-assessment of TPACK in Texas community college faculty, this researcher examined 329 studies for appropriateness in five stages (see Table 3). In Stage 1, the studies that were unavailable, not in English, were theory-development articles, or strictly qualitative studies were eliminated, leaving 169 articles to evaluate further. In Stage 2, mixed-methods studies that did not use a survey, failed to include the survey in the article, did not use a TPACK survey, or used a survey that did not measure all seven facets of TPACK were removed, leaving 129 studies for further inspection. In Stage 3, empirical studies that did not have an appropriate TPACK survey were eliminated. Meta-analyses were excluded, as were articles in which survey instruments were not included, studies that included a survey but were not designed to measure the seven factors of TPACK as theorized by Mishra and Koehler (2006; e.g., Yurdakul, Odabasi, Kilicer, Coklar, Birinci, & Kurt, 2012), or did not measure faculty TPACK, leaving 98 studies still to be reviewed. Stage 4 eliminations required a deeper analysis of the articles; studies where the survey itself was not in English or the TPACK model was substantially different from the 7-factor model (e.g., Holland & Piper, 2016) were removed, leaving 64 studies to analyze. Stage 5 eliminations focused on specific issues indicating an instrument might not be appropriate for this particular study (see Table 3).

Round 5 of study analysis removed 31 studies that did not conduct a factor analysis. The present study sought an instrument to collect valid and reliable data in Texas community college faculty. It is important that factor loadings from the original study and the present study can be compared. Further, 16 studies in which the authors were unable to extract all seven factors of TPACK were removed. The present study sought an instrument that can measure all seven factors; consequently, it was appropriate to remove these from consideration. Eleven studies that failed to meet the 10:1 respondents-to-item ratio as they may have suffered from sample size specificity, therefore lacking generalizability were also removed (Hair et al., 2016). Finally, two discipline-specific instruments (e.g., chemistry, geography) were eliminated as the present research tested self-assessment of TPACK in Texas community college faculty across disciplines. This left only four studies to analyze closely. Table 3 includes details (e.g., fit statistics) for the final four studies.

The final four studies detailed in Table 4 included studies by Celik, Sahin, and Akturk (2014); Chai, Ng, Li, Hong, and Koh (2013); Koh, Chai, and Tsai (2013); and Koh, Chai, and Tsai (2014). Celik et al. (2014) surveyed 744 preservice teachers in Turkey using Sahin’s (2011) 47-item instrument without any alterations. Chai, Ng, Li, Hong, and Koh (2013); Koh, Chai, and Tsai (2013); and Koh, Chai, and Tsai (2014) all used an adaptation of Chai, Koh, and Tsai’s (2011) instrument, which itself was a derivative of the Schmidt et al. (2009) survey. Chai, Ng, Li, Hong, & Koh (2013) surveyed 550 preservice teachers in China, Hong Kong, Singapore, and Taiwan with a 36-item instrument. Koh, Chai, & Tsai (2013) used a 30-item instrument to measure

Table 3

*Elimination criteria for studies*

| Elimination Criteria | No. of studies | % of total studies | Studies to evaluate |
|---|---|---|---|
| Initial studies to evaluate | | 100.00% | 329 |
| *Stage 1* | | | |
| Article not available through ILL | 14 | 4.26% | 315 |
| Article not in English | 7 | 2.13% | 308 |
| Theory-development articles | 26 | 7.90% | 282 |
| Qualitative articles | 113 | 34.35% | 169 |
| *Stage 2* | | | |
| Mixed methods–no survey used | 9 | 2.74% | 160 |
| Mixed methods–survey not included in article | 11 | 3.34% | 149 |
| Mixed methods–non-TPACK survey | 9 | 2.74% | 140 |
| Mixed methods–not all 7 factors of TPACK | 11 | 3.34% | 129 |
| *Stage 3* | | | |
| Empirical–meta-analyses | 2 | 0.61% | 127 |
| Empirical–survey not included in article | 1 | 0.30% | 126 |
| Empirical–not intended to measure Mishra & Koehler's (2006) theory of TPACK | 27 | 8.21% | 99 |
| Empirical–does not measure faculty | 1 | 0.30% | 98 |
| *Stage 4* | | | |
| Survey not in English | 7 | 2.13% | 91 |
| Model substantially different from Mishra & Koehler (2006) | 10 | 3.04% | 81 |
| Basic factors only (CK, PK, TK, & TPACK) | 4 | 1.22% | 77 |
| Intermediate factors only (PCK, TPK, TCK, & TPACK) | 1 | 0.30% | 76 |
| Technology factors only (TK, TPK, TCK, & TPACK) | 12 | 3.65% | 64 |
| *Stage 5* | | | |
| Did not conduct factor analysis | 31 | 9.42% | 33 |
| Failed to extract all 7 factors | 16 | 4.86% | 17 |
| Inadequate sample size | 11 | 3.34% | 6 |
| Discipline-specific | 2 | 0.61% | 4 |

TPACK in 455 in-service primary, secondary, and junior college teachers in Singapore. The final study to examine in-depth was a survey of 354 in-service teachers in Singapore with a 32-item instrument by Koh, Chai, and Tsai in 2014.

The survey instrument used in Celik, Sahin, and Akturk (2014) did not address learner-centered pedagogical practices, a key component of the *60x30TX* plan that prompted this study in Texas community college faculty. The instrument in Celik et al. contained 47 items, making it the longest of the four studies under review, which could make achieving adequate sample size problematic in the present research. In addition, some fit indices are inconsistently reported between Table 1 (p. 8) and article text (p. 9), creating a lack of confidence in the data reporting. The three studies left to review come from the same core research team (Chai, Ng, Li, Hong, & Koh, 2013; Koh, Chai, & Tsai, 2013; Koh, Chai, & Tsai, 2014) and all evolved from the Chai, Koh, and Tsai (2011) instrument. A close review of items from Koh, Chai, and Tsai (2013) show context-specific items (e.g., TPACK 3 "I can use strategies that combine content, technologies and teaching approaches that I learned about in my coursework in my classroom"), making it unsuitable for the current study.

As reliability and fit statistics are very similar between the two remaining studies, an item comparison was conducted (see Appendix D) to determine whether to use the Chai et al. (2013) or the Koh et al. (2014) survey instruments for the present research. Differences between the two studies include a complete replacement of TK items in Koh et al. to focus on constructivist-oriented (i.e., learner-centered) technologies. Koh et al. replaced the more general "my teaching subject" in Chai et al.'s study of preservice

Table 4

*Comparison of four instruments to measure self-assessment of TPACK in faculty*

| Author | Survey Lineage | N | Target Population | # items retained | EFA CFA or SEM | Alpha | $\chi^2$ | *df* | *p* | TLI | CFI | RMSEA | SRMR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Celik, Sahin, & Akturk, 2015 | Sahin 2011 | 744 | Preservice teachers in Turkey | 47 | SEM | .86–.93 | 7.625 | 5 | 0.178 | 0.994 | 0.998 | 0.039 | NR |
| Chai, Ng, Li, Hong, & Koh, 2013 | Chai, Koh, & Tsai 2011 | 550 | Preservice teachers in China, Hong Kong, Singapore, and Taiwan | 36 | CFA | .88–.92 | 1134.500 | 411 | <.001 | 0.950 | 0.960 | 0.050 | NR |
| Koh, Chai, & Tsai, 2013 | Chai, Koh, & Tsai 2011 | 455 | In-service primary, secondary, and junior college teachers in Singapore | 30 | CFA<br>SEM | .89–.95 | 1008.340 | NR | <.0001 | 0.940 | 0.950 | 0.060 | 0.050 |
| Koh, Chai, & Tsai, 2014 | Chai, Koh, & Tsai 2011 | 354 | In-service teachers in Singapore | 32 | EFA<br>CFA | .92–.96 | 1139.600 | NR | <.0001 | 0.940 | 0.950 | 0.067 | 0.036 |

teachers in China, Hong Kong, Singapore, and Taiwan with “my first teaching subject (CS1)” in their study of in-service teachers in Singapore to reflect the different cultural contexts of these studies. Koh et al. deleted items CK4, PCK4, PCK5, PCK6, PCK8, and TPCK6 that are included in the Chai et al. study.

Item CK4 measured self-confidence in teaching the content rather than a self-assessment of content knowledge, making it a good choice for deletion as it does not measure the CK construct. Koh et al. explained the revision of PCK items as an attempt to better align the items to Shulman’s (1987) definition of PCK while adjusting the items to learner-centered practices by focusing on “teachers’ facilitation of students’ thinking by addressing their difficulties with content knowledge” (p. 188). Item TPCK6 is a generalized item regarding lesson planning that appears to be better addressed with the more specific learner-centered activities in items TPACK1 through TPACK5.

## Summary

The survey instrument from the Koh, Chai, and Tsai (2014) survey was used as the base for the present study. The scientific literature review process following Voogt et al. (2012) identified the following: TPACK literature for evaluation, elimination stages used to determine appropriate instruments for detailed evaluation, the examination of reliability and fit statistics, and its constructivist nature, making the Koh, Chai, and Tsai (2014) survey the most appropriate instrument found in the literature at this time. Moreover, it is appropriate to use a constructivist-oriented instrument in Texas community college faculty as learner-centered instructional strategies are encouraged in community colleges and deeply embedded in the *60x30TX* plan (Bailey et al., THECB, 2015).

# Chapter Three – Methodology

The present research used a cross-sectional research design to exam the reliability and validity of the research instrument in full- and part-time Texas 2-year public college faculty. The sample was randomly selected from the email addresses of all full- and part-time Texas community college faculty gathered through a public information records request. A rigorous literature review process identified the research instrument selected, as detailed in Chapter 2. Following instrument selection, an expert committee convened to review the survey for appropriateness and made minor alterations for context and technology (e.g., Mishra & Koehler, 2006; Graham, 2011). The revised instrument used in this study is the Community College–TPACK Survey for Meaningful Learning (CC–TSML).

Participants were recruited by email for the online survey, which was expected to take approximately 8 minutes to complete. The dependent variable (TPACK) was presented first, followed by intermediary variables (PCK, TCK, and TPK), independent variables (CK, PK, and TK), and finally demographics questions. The survey featured an instructional manipulation check (Oppenheimer, Meyvis, & Davidenko, 2009) and CFA marker items to test for common method variance (Williams, Hartman, & Cavazotte, 2010). A variety of methods were used to increase response rates (e.g., Fan & Yan, 2010; Dillman, Smyth, & Christian, 2014) and combat common method bias (e.g., Podsakoff et al., 2003; Podsakoff et al., 2011). Data collection took place between Monday, January 29, 2018, and Wednesday, February 7, 2018.

## Research Design

The current study used a quantitative cross-sectional research design to examine the validity and reliability of data collected with the CC–TSML. Survey methodology was used to gather the data. Data were analyzed using sequential exploratory–confirmatory factor analysis procedures (Worthington & Whittaker, 2006) to examine, refine as necessary, and confirm the factor structure of the CC–TSML data (Byrne, 2010). Hypotheses were tested using pattern coefficients, structure coefficients, composite reliability (CR), convergent reliability, discriminant validity testing, and global and local fit indices.

## Population

The target population for this study included full- and part-time faculty in public 2-year colleges in Texas. In Texas, the only publicly available data for community college faculty indicate institution, gender, and ethnicity (THECB, 2017). According to THECB data from 2015, the most current year for which data is available, the Texas 2-year public college professorate consists of 34.71% full-time and 65.29% part-time faculty. The community college faculty in Texas is 53.90% female and 46.10% male (THECB, 2017). Closer examination of the data showed that an overwhelming majority of the 2-year public college professorate identify as White (63.59%), while 14.40% identify as Hispanic, 12.37% identify as African American, 4.87% identify as Asian, 4.49% identify as Other, and 0.28% identify as International (THECB, 2017). Further detail of Texas 2-year public faculty population is found in Table 7.

## Sample Size

Exploratory factor analysis and confirmatory factor analysis procedures require large sample sizes so that the probability of errors is minimized, the accuracy of population estimates is maximized, and the generalizability of the results is increased (Osborne & Costello, 2004). Subject-to-item sample size guidelines for reliability in EFA and CFA analyses range from a high of 20:1 (cf. Thompson, 2004) to a low of 3:1 (Cattell, 1966). Generally, a 5:1 ratio is considered "minimum" while a 10:1 ratio is "acceptable" (Hair et al., 2015; Osborne & Costello, 2004; Thompson, 2004). Using these guidelines to conduct a sequential EFA–CFA using the CC–TSML including the Attitudes Towards the Color Blue (ATTCB) items, this study required a minimum of 600 participants for the 40-item research instrument.

According to a study by Wolf, Harrington, Clark, and Miller (2013) regarding sample size for CFA and SEM models, sample size for these models fluctuates depending on a variety of influences (e.g., number of latent variables, factor loadings, number of indicators per factor). In CFA models, Wolf et al. found that while there was a significant increase in sample-size needs for a 2-factor model over a single-factor model, changes between a 2-factor and 3-factor model were "not associated with a concomitant increase in sample size" (p. 8). Sample-size calculations for this study using Tables 2 and 3 from Wolf et al. (2013) indicated that 560 participants were sufficient to conduct the CFA while the total study should have a sample size of 840 (see Table 5). While Koh et al. (2014) showed statistically significant correlations among all the factors, only some met the Wolf et al. (2013) threshold of factor correlations greater than .50 that would have allowed consideration of a less stringent sample-size calculation (Wolf et al., 2013). In order to conduct the sequential EFA–CFA, using the sample-size guidelines from Wolf et al. (2013) for CFA sample size and extrapolating for the one-third–two-thirds split, sample size needed for this study was 840 participants.

Table 5

*Sample size for CFA using Wolf et al., 2013*

| Construct | Number of Indicators | Number of Factors | Indicators Per Factor | Avg. Factor Loading Range | Respondents Per Construct |
|---|---|---|---|---|---|
| Content Knowledge (CK) | 3 | 1 | 3 | .80 | 60 |
| Pedagogical Content (PK) Knowledge (PCK) | 3 | 1 | 3 | .91 | 60 |
| Pedagogical Knowledge (PK) | 6 | 1 | 6 | .81 | 40 |
| Technological Pedagogical Content Knowledge (TPACK) | 5 | 1 | 5 | .72 | 90 |
| Technological Pedagogical Knowledge (TPK) | 5 | 1 | 5 | .68 | 90 |
| Technological Content Knowledge (TCK) | 3 | 1 | 3 | .67 | 90 |
| Technological Knowledge (TK) | 7 | 1 | 7 | .80 | 40 |
| Attitudes Towards the Color Blue (ATTCB) | 8 | 1 | 8 | .50 | 90 |
| Total CFA Sample Size[a] | | | | | 560 |
| Sequential EFA–CFA Sample Size[b] | | | | | 840 |

*Note*. a = CFA will use two-thirds of the total sample. b = EFA will use one-third of the total sample.

## Instrumentation

A detailed examination of the TPACK literature identified the Koh et al. (2014) instrument as the most appropriate one for use in the present study. A detailed analysis of the TPACK literature and search for an instrument is contained in Chapter 2. An expert committee examined the TPACK Survey for Meaningful Learning (TSML; Koh et al., 2014) to ensure its appropriateness for the community college context (e.g., Mishra & Koehler, 2006) and for technology examples (e.g., Mishra & Koehler, 2006; Cox & Graham, 2009; Graham 2011).

An expert committee reviewed items from the Koh et al. (2014) survey in May 2017 to ensure their face validity in the target population of the current study. The expert committee consisted of six members representing community college and university faculty, full-time and part-time faculty, and various subject areas (e.g., chemistry, English, education). Each item was reviewed, discussed, revised (if necessary), and voted on as committee members formed a consensus. Highlights of item changes include changing "first teaching subject (CS1)" to "teaching subject," changing "ICT" to "digital technology," and removing or revising examples in some questions. This revised instrument was termed the Community College TPACK Survey for Meaningful Learning (CC–TSML). Details of item changes and expert committee rationale are included in Appendix E.

The CC–TSML items, items to test for common method variance (Miller & Chiodo, 2008), and demographic questions were used in this study. The total number of items for the CC–TSML was 40. The CC–TSML is a minor revision of the survey reported in the 2014 Koh et al. study. The instrument as reported in Koh et al. (2014) was developed over several studies (e.g., Chai, Ng, Li, Hong, & Koh, 2011; Koh, Chai, & Tsai, 2013; Koh & Chai, 2014), has demonstrated validity and reliability across several studies, and has shown relatively consistent fit statistics (see Table 4).

While no full nomological study has been conducted to confirm construct validity using the instrument selected, Koh, Woo, and Lim (2013) conducted a study of 869 Singaporean preservice teachers' computer technology course experiences and TPACK using a course evaluation instrument. The course evaluation instrument included 14 questions designed to measure course experience variables and 30 questions from Chai et al. (2013) TPACK instrument, a closely related instrument to the one that underpins this study (see Table 4). The course experience variables of course delivery, course content, and course environment were adapted from the Technology Acceptance Model survey (Teo, Lee, Chai, & Wong, 2009). Koh, Woo, and Lim (2013) argue that perceptions of course content, delivery, and learning environment can directly influence perceived ease of use, a major construct of the Technology Acceptance Model (TAM; Davis, 1989).

Koh, Woo, and Lim's (2013) correlational analysis found strong correlations (.50 > |r|; Ward, Fischer, Lam, & Hall, 2009) between course content and PK, TPK, TCK, and TPACK, providing some validity to the idea that perceived ease of use strongly influences pedagogical and technological constructs of TPACK. Strong correlations between course delivery and TPACK indicated that the methods used to deliver the training can have a strong influence on a teacher's TPACK development. No strong correlation was found between learning environment and any TPACK factors. Moderate correlations (.30 < |r| < .50; Ward et al., 2009) were found between course content and CK and TK, indicating the sample population perceived only a modest boost in their content and technical knowledge. Moderate correlations between course delivery and CK, PK, TK, TPK, and TCK suggested that the preservice Singaporean teachers' perceived ease of use was modestly influenced by the course delivery methods across most facets of

TPACK. The moderate influence between learning environment and all TPACK variables supported that suggestion. Weak correlations (.10 < |r| < .30; Ward et al., 2009) between course content and PCK and between course delivery and PCK suggested relatively little influence of perceived ease of use on their content-related teaching methodologies.

### Content Knowledge (CK)

This subscale purported to measure individuals' self-assessment of their knowledge of the subject matter (Koh, Chai, & Tsai, 2011; Mishra & Koehler, 2006). It consisted of three items with factors loadings of .77 ("I have sufficient knowledge about my first teaching subject") to .84 ("I can think about the content of my first teaching subject [CS1] like a subject matter expert"). Coefficient alpha for this subscale was calculated as .95 (Koh, Chai, & Tsai, 2014). Composite reliability was adequate as calculated (.85) and convergent reliability was adequate with factor loadings greater than or equal to .50 and average variance extracted calculated as .65 (Bagozzi & Yi, 1988).

### Pedagogical Knowledge (PK)

This subscale was designed to measure individuals' self-assessment of their knowledge of teaching methods (Mishra & Koehler, 2006); this scale specifically focused on learner-centered teaching methodologies (Chai, Koh, Tsai, & Tan, 2011). Factor structure loadings for this six-item subscale showed a range of .77 to .83 ("I am able to help my students to reflect on their learning strategies"). A coefficient alpha of .94 was reported (Koh, Chai, & Tsai, 2014). Using Bagozzi and Yi's (1988) benchmarks, this subscale demonstrated adequacy with composite reliability calculated at .92 and convergent reliability with an average variance extracted calculated as .65.

### Technological Knowledge (TK)

This seven-item subscale was intended to measure self-reported knowledge about current common technologies (Mishra & Koehler, 2006). This subscale produced factor loadings from .66 to .87 ("I am able to use online sticky notes [e.g., Diigo, Wallwisher]"). Internal reliability was reported as coefficient alpha of .94 (Koh, Chai, & Tsai, 2014). Convergent reliability is adequate with a calculated average variance extracted of .64 and composite reliability of .93, meeting Bagozzi and Yi's (1988) recommended benchmark values.

### Pedagogical Content Knowledge (PCK)

This three-item subscale purported to measure the self-report knowledge of faculty in teaching methods specific to content (Mishra & Koehler, 2006) and was adjusted for learner-centered focused teaching methodologies by Chai, Koh, and Tsai (2011). Reported factor loadings ranged from .89 to .93 ("Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my first teaching subject [CS1]"). Internal reliability for this subscale was calculated as $\alpha = .93$ (Koh, Chai, & Tsai, 2014). Both composite reliability and convergent reliability of this subscale were deemed adequate using Bagozzi and Yi's (1988) benchmarks with composite reliability calculated as .94 and average variance extracted as .83.

### Technological Content Knowledge (TCK)

This three-item subscale was designed to capture individuals' self-assessment of the technologies associated with their content area (Mishra & Koehler, 2006). Coefficient alpha for this three-item subscale was reported as .92 in Koh, Chai, and Tsai (2014). Factor loadings ranged from .61 to .74 ("I can use the software that are created specifically for my first teaching subject [CS1]. [e.g., e-dictionary/corpus for language; Geometric sketchpad for Maths; Data loggers for Science]") in 2014 by Koh, Chai, and Tsai. Composite reliability for this subscale equaled .71, exceeding the suggested benchmark value of Bagozzi and Yi (1988). Convergent reliability for this subscale was not demonstrated using the Bagozzi and Yi (1988) suggested values. Pattern coefficients met the benchmark (≥ .50); however, the average variance extracted equaled .45, falling short of Bagozzi and Yi's (1988) suggested benchmark (≥ .50).

### Technological Pedagogical Knowledge (TPK)

This five-item subscale was designed to measure self-report data on knowledge of teaching methods using technology (Mishra & Koehler, 2006). This scale was reframed using learner-centered principles by Chai, Ng, Li, Hong, and Koh (2011). Factor loadings for this five-item subscale range from .63 to .74 ("I am able to facilitate my students to use technology to plan and monitor their own learning." Internal reliability was reported as .95 (Koh, Chai, & Tsai, 2014). The composite reliability for this subscale found a value of .81, meeting Bagozzi and Yi's (1988) benchmark for adequacy. Convergent reliability for this scale was not determined adequate as pattern coefficients were all greater than .50; however, the average variance extracted was only .46 (Bagozzi & Yi, 1988).

### Technological Pedagogical Content Knowledge (TPACK)

This five-item subscale was designed to measure self-report data on individuals' knowledge of using a variety of technologies and methodologies specific to their content area (Mishra & Koehler, 2006). Chai, Ng, Li, Hong, & Koh (2011) refocused these items on learner-centered principles. This subscale generated factors loadings from .65 to .75

("I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools [e.g., simulations, web-based materials]"). Koh, Chai, and Tsai (2014) calculated coefficient alpha for this subscale as .96. Both convergent and composite reliability for this subscale were demonstrated with composite reliability calculated as .84 and average variance extracted as .52 (Bagozzi & Yi, 1988).

### Attitudes Towards the Color Blue (ATTCB)

In order to control for common method variance (CMV), the CFA marker technique from Williams, Hartman, and Cavazotte (2010) was employed. In order to accomplish this, an eight-item marker variable set—Attitude Towards the Color Blue (ATTCB)—was used (Miller & Chiodo, 2008) as the unrelated marker (Williams et al., 2010). Items for this variable set were measured on a 7-point Likert-type scale where 1 = *Strongly disagree* and 7 = *Strongly agree* (Miller & Chiodo, 2008).

## Survey Design

The CC–TSML instrument was created using Qualtrics. The Qualtrics features to prevent "ballot box stuffing" was activated to ensure participants took the survey only one time (Johnson & Borden, 2012).  A single screening question verifying employment status as a full- or part-time faculty member was used. Efforts to increase response rates to the survey included using an official University of Texas at Tyler header to demonstrate official sponsorship by an educational institution, leading to higher response rates than a commercial or nonsponsored survey would (Fan & Yan, 2010). The CC–TSML is directly related to teaching competencies of community college faculty and should have high topical salience for the targeted sample, a feature that may increase response rates, according to Fan and Yan (2010; see Recruiting Email in Appendix F).

Studies show that surveys that take 13 minutes or less achieve good response rates (Fan & Yan, 2010). Qualtrics estimates this survey would take 8 minutes to complete, which matches the mean completion time in a nonscientific trial with 29 individuals (mean = 8 minutes) undertaken by this researcher. Following the screening question, the consent block of the survey displayed the informed consent that assures anonymity (Reio, 2010). Participants opted into the survey by choosing the "Yes, I choose to participate in this study." A copy of the informed consent text is included in Appendix G.

Participants who chose to participate in this survey were presented with the substantive variables in the following order: the dependent variable (TPACK), intermediary variables (PCK, TPK, TCK), and independent variables (TK, PK, CK) to combat common method bias, specifically item priming effects (e.g., Podsakoff et al., 2003; Podsakoff et al., 2011). An instructional manipulation check was included to ensure participants were still cognitively engaged in the survey (e.g., Oppenheimer et al., 2009). Items for a CFA marker variable were included to allow for common method bias testing (e.g., Williams et al., 2009) and were displayed once per participant between the DV and intermediary variables and between the intermediary variables and the IVs, using Qualtrics features to randomly alternate these blocks and others (see Table 6). A small trial (*n* = 10) of the CC–TSML created in Qualtrics for this study indicated that all screening features, randomization of alternating blocks, and required questions features were functioning as designed. Demographics followed the IVs. A back button was not used in order to maintain the physical separation between variables to combat consistency motif effects (Podsakoff et al., 2003; Podsakoff et al., 2011). Due to the question block design of the survey, a progress bar was not used as it would not accurately reflect how many more items the participant had yet to complete.

To alleviate participant evaluation apprehension, instructions were placed at the top of each substantive question screen informing participants that there were no correct answers, their honest responses were desired, and their responses were anonymous (Dillman et al., 2014). The matrix design of substantive questions with Likert scale responses and radio button selection options for demographics items provided a commonly used visual framework leading participants to feel at ease with the survey completion task (Dillman et al., 2014; Fowler, 2014).

Table 6

*CC–TSML screen sequences*

| Screen 1 | Screen 2 | Screen 3 | Screen 4 *alternate /random* | Screen 5 *random* | Screen 6 *alternate /random* | Screen 7 *random* | Screen 8 |
|---|---|---|---|---|---|---|---|
| Screen Question | Consent | TPACK (DV) | ATTCB<br>IMC | PCK<br>TPK<br>TCK<br>(Intervening) | IMC<br>ATTCB | CK<br>TK<br>PK<br>(IVs) | Demographics |

*Note.* CC-TSML = Community College TPACK Survey for Meaningful Learning.

Screen 1 displayed the screening question to ensure only full- or part-time instructional faculty completed the survey. Those who failed the screening question were not permitted to continue the survey. Screen 2 displayed the informed consent for the study (see Appendix G). The dependent variable (TPACK) presented in Screen 3 consisted of construct items grouped together and shown in the order of publication (Koh et al. 2014). Dependent variable (TPACK) items appeared first as a way to prevent item priming effects, combat proximity effects, and create temporal and psychological separation between IVs and DVs (Podsakoff et al., 2003; Podsakoff et al., 2011).

On Screen 4, the ATTCB CFA marker variable items (cf. Williams et al., 2010) or the instructional manipulation check (IMC) question (Oppenheimer et al., 2009) appeared (see Table 6). Screen 4 and Screen 6 were connected so that when participants saw the ATTCB questions on Screen 4, they could also see the IMC question on Screen 6. This functionality was verified prior to deployment of the survey. The CFA marker variable items and IMC served as both the necessary cognitive break to combat consistency motif bias (Podsakoff et al., 2011; Podsakoff et al., 2003) and ensure participants were not exhibiting fatigue. Failing the IMC did not discontinue the survey for participants as that could negatively affect external validity of the study (Oppenheimer et al., 2009).

On Screen 5, the items (questions) within the intervening variable blocks (PCK, TCK, and TPK), and Screen 7, showing the items for the IVs (CK, PK, and TK), were displayed in the same order as shown in Koh, Chai, and Tsai (2014). The variables were presented in random sequence to ameliorate some common method bias issues (Podsakoff et al., 2003; Podsakoff et al., 2011; Reio, 2010). Items for all intervening variables (PCK, TPK, and TCK) were shown on Screen 5. The decision to group intervening variables on one screen (Screen 5) and IVs on another screen (Screen 7) was made to limit the number of screens viewed by participants in order to increase survey response completion (Fan & Yan, 2010). Screen 6 showed either the ATTCB questions or the IMC question, depending on which the participant was shown in Screen 4.

Independent variables (CK, PK, TK) were randomized in screen 7 with items shown within the blocks as reported by Koh, Chai, and Tsai (2014). This process honored the original published sequence of questions for each construct but presented the constructs in random order. These efforts were undertaken to combat a host of common method bias issues identified in Podsakoff et al. (2003) including those associated with common raters (e.g., consistency motif), measurement context (e.g., time of measurement), and item context (e.g., item priming effects).

Demographic variables were collected on one screen, including data on gender, ethnicity, age range, birth year, number of college credits in teaching methods or pedagogy, number of college credits in educational technology or teaching with technology, high school-level teaching certification status, institutional affiliation, and employment status (e.g., full time, part time). Demographic item response choices for gender and ethnicity matched data reported from THECB (2017) as shown in Table 7 to facilitate comparison of the sample to the population. Gender choices were limited to female or male; status choices were limited to full time or part time; and ethnicity choices were limited to African American, Asian, Hispanic, International, Other, and White (THECB, 2017; see Table 7); and institutional affiliation was presented alphabetically by institution name in a drop-down list based on THECB (2017) listings.

While the use of the age range, birth year, number of college credits in teaching methods or pedagogy, number of college credits in educational technology or teaching with technology, high school-level teaching certification status, and institutional affiliation data is beyond the scope of this dissertation, the data were collected in anticipation of further analysis post-dissertation. The age ranges used (e.g., under 30, 30 to 34, 35 to 40…60 to 64, 65 or older) were identical to the age ranges used by the Institute of Education Sciences for their Digest of Education Statistics (2013). Birth year information was collected so generational cohorts can be formed at a later date. Generational cohorts are important to study because these groups have been influenced by social values emphasized in particular periods of history (Li & Nimon, 2008). By collecting birth year data, this researcher has the flexibility to build generational cohorts based on the most current literature at the time of analysis. Currently, there is disagreement over the inclusive years for generational cohorts (Clardy, 2017).

Demographics questions asking about participants prior college preparation in teaching methods or pedagogy and educational technology or teaching with technology were included so that Texas community college faculty can later be compared to Texas secondary faculty (TEA, 2018; TEC §21). The demographics question asking participants if they had held a high school level teaching certificate in any area in the last 15 years was included to capture all previously certified teachers that may have been certified outside of Texas or who might have been certified in a career or technical education field (e.g., culinary arts).

The demographic questions were placed at the end of the instrument as suggested by Stoutenbourgh (2008). This decision was made in an attempt to prevent noncompletion based on the potential of demographics questions to make respondents uncomfortable and to allow survey questions to be completed prior to the “boring” (Teclaw, Price, & Osatuke, 2012) questions associated with demographics. Even though demographic information was collected, no personal identifying information was gathered and anonymity was guaranteed, as stated in the consent block and instructions for each question screen (Dillman et al., 2014).

## Data Collection

Before data collection could begin, a database of the population had to be developed. The Texas community college faculty database was created by making Public

Information Act requests to all 50 community college districts in Texas and consolidating all the email addresses into one spreadsheet. For more information on the Public Information Act requests and collection of faculty email addresses, please see Appendix B. All 50 community college districts responded resulting in the acquisition of 33,871 email addresses (see Appendix C).

Documents for The University of Texas at Tyler's Institutional Review Board were prepared when the researcher's committee approved the dissertation proposal. Those documents were submitted to the dissertation chair for review and then were submitted for IRB review. IRB approval was granted (see Appendix J).

Data were collected using a Qualtrics online survey in the Spring 2018 semester. Respondents were recruited via email using email addresses from the Texas community college faculty database. The database included 33,871 Texas community college faculty email addresses (see Appendix C). Due to constraints within the Qualtrics mailer that allow the current researcher to send only 50,000 emails per week and the desire to send an invitation email and the first follow up email in the same week, the researcher was constrained to using 25,000 Texas 2-year college email addresses at one time. The Select Cases feature in IBM® SPSS was used to randomly select 25,000 email addresses for inclusion in the initial study email invitation from the collection of email addresses.

Participation was anonymous and voluntary; participants could withdraw at any time with no penalty. No personally identifying information was collected. Participation was limited to full- and part-time faculty at 2-year public colleges in Texas. An invitation email was sent including a generic link to the survey and two reminder emails were sent to participants who had not yet completed the survey. Text of the invitation email and two reminder emails are contained in Appendix F. The invitation email was sent on Monday, January 29, 2018, between 6:00 a.m. and 7:00 a.m., as research suggests that response rates are higher during this time (Dillman et al., 2014). Following guidelines in Dillman et al. (2014), Reminder 1 email (see Appendix F) was sent early in the morning before working hours three days later on Thursday, February 1, 2018. Reminder 2 email was sent early in the morning the following Monday, February 5, 2018 (one week after initial contact).

## Data Analysis

In order to test for the reliability and validity of the data collected with the CC–TSML, a sequential EFA–CFA was performed (Bates, Holton, & Hatala, 2012; Worthington & Whitaker, 2006). Data analysis was conducted using IBM® SPSS AMOS version 24. The SPSS random selection feature was used to split the cleaned data sample (*n* = 1,299). One-third of the responses (*n* = 433) were used to conduct an EFA while the remaining two-thirds of the responses (*n* = 866) were used to perform a CFA (Bates et al., 2012; Thompson, 2004; Worthington & Whittaker, 2006). Although the data collected represented clustered data (e.g., individuals within institutions), Heck (2001) noted that CFA analyses have traditionally permitted using the “lowest level of measurement (i.e., scores from individuals)” (Huang, 2017, p. 2) or “microlevel” (p. 91) for conducting single-level analysis. Therefore, the present research used a single-level CFA analysis as individual scores were not aggregated into a “macrolevel” (Heck, 2001, p. 91; Huang, 2017).

## Data Cleaning

After collection, the data were evaluated to determine whether any cases needed to be eliminated from the analyses. Range of values were inspected to ensure that no data points fell outside the scale values. Any cases with missing data were removed from evaluation. Data were evaluated for straight-lining within the marker variable and overall time to complete the survey (Cole, McCormick, & Gonyea, 2012; Oppenheimer et al., 2009). Data from participants who straight-lined the marker variable and who failed the minimum survey length were eliminated from analysis. While it is possible that straight-line responses are valid according to Cole et al. (2012), it appears unlikely if they also fail the minimum survey length. To determine minimum survey length, a convenience sample of 29 respondents indicated that the mean time to complete the survey was 8 minutes with a standard deviation of 4 minutes. Survey minimum length was set for 4 minutes (mean – SD) and the maximum length set for 14 minutes (mean + 1.5SD). Participants who took less than 4 minutes or more than 14 minutes to complete the survey were eliminated from analysis (Johnson & Borden, 2012).

## Statistical Assumptions

Data analysis was conducted using IBM® SPSS AMOS version 24. A foundational assumption of EFA is that there is some underlying structure that exists in a set of variables (e.g., Hair et al., 2015). Both TPACK theory and previous empirical research indicate that structure does exist among the seven variables (e.g., Chai, Koh, & Tsai, 2011; Koh, Chai, & Tsai, 2014; Mishra & Koehler, 2006). Tests to determine whether sufficient correlations exist among the items included the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett’s test of sphericity (e.g., Hair et al., 2015). A KMO > .50 and a statistically significant result ($p < .05$) on Bartlett's test of sphericity indicated the data were sufficiently correlated to proceed with factor analytics (e.g., Hair et al., 2015).

The covariance matrix was used in the CFA study as it is considered preferable to the correlation matrix in this analysis (cf. Thompson, 2004). Statistical tests for multivariate normality and multivariate outliers were performed in the CFA phase (e.g., Byrne, 2010; Kline, 2016; Thompson, 2004). Multivariate normality was tested by assessing the critical ratio ($t$ or Wald statistic) for a value greater than 5.00, which indicates non-normality (e.g., Byrne, 2010; Kline, 2016; Thompson, 2004). Multivariate outliers were examined with the squared Mahalanobis distance ($D^2$) test (e.g., Kline, 2016). Byrne (2010) suggested that researchers examine $D^2$ for outliers by comparing them to other $D^2$ values looking for "value[s] that stand distinctively apart from all other $D^2$ values" (p. 106). When the data failed the test of multivariate normality, bootstrapped data using 2,000 cases (Thompson, 2004) with 95% bias-corrected confidence intervals (Kline, 2016) were compared to non-bootstrapped data. Given there were no statistically significant differences between them, the non-bootstrapped data were used (Kline, 2016). Cases with missing data were removed in the data-cleaning process, so they were not a factor in these analyses. Maximum likelihood parameter estimation was used (e.g., Kline, 2016; Thompson, 2004). Factor rotation is not necessary in CFA (e.g., Hair et al., 2013; Thompson, 2004).

## Exploratory Factor Analysis

After data cleaning, the data were split, and one-third of the data ($n = 433$) were used to conduct an exploratory factor analysis (e.g., Thompson, 2004). The EFA was conducted following common procedures (e.g., Hair et al., 2015; Kline, 2016; Thompson, 2004). The matrix of association used in the present study was the Person product-moment bivariate correlation matrix ("correlation matrix") most often associated with EFA (e.g., Thompson, 2004). The Kaiser–Meyer–Olkin measure of sampling adequacy (KMO > .50) and a statistically significant result ($p < .05$) on Bartlett's test of sphericity indicated the data were sufficiently correlated to proceed with the factor analysis (e.g., Hair et al., 2015).

Maximum likelihood (ML) estimation was employed for the factor extraction as it "focuses on creating factors that reproduce the correlation or covariance matrix in the population, versus in the sample" (Thompson, 2004, p. 38), as this study is most interested in population estimates. An *a priori* factor structure was used based on the successful extraction of all seven TPACK factors in previous research (e.g., Chai, Koh, & Tsai, 2011; Hair et al., 2015; Koh, Chai, & Tsai, 2014; Thompson, 2004). Oblique promax rotation was used as the data were expected to be correlated and promax is an iterative process beginning with an orthogonal rotation (Hair et al., 2015; Kline, 2016; Thompson, 2004). Because oblique rotation was used, the factors were allowed to correlate with each other, meaning no identity matrix was formed, and therefore no test for that was necessary (Henson & Roberts, 2006).

Convergent validity was assessed by reviewing the pattern matrix for "strong loaders (.50 or better)" (Costello & Osborne, 2005, p. 4). The pattern matrix was examined for items that cross-loaded, that is, items that loaded on more than one factor with the secondary loading at .32 or above (Costello & Osborne, 2005) to assess discriminant validity. The structure matrix was evaluated to ensure that items loaded most heavily on their respective factors (Graham et al., 2003). Items with pattern coefficients less than .50, that had cross-loadings of .32 or greater, and structure coefficients that did not load most heavily on their expected factor were removed (e.g., Costello & Osborne, 2005; Graham et al., 2003; Hair et al., 2015). After the item was removed, the analysis began again until a simple factor structure was identified (Hair et al., 2015; Thompson, 2004). Reliability was evaluated by inspecting Cronbach's alpha for values greater than .80 for each subscale (Henson, 2001). The EFA hypotheses are included here to assist the reader.

### EFA Hypotheses

H1.1: Pattern coefficients will be greater than .50 with cross-loading of less than .32 (e.g., Costello & Osborne, 2005).

H1.2: Structure coefficients will load most heavily on their respective factors (Graham, Guthrie, & Thompson, 2003).

H1.3: Cronbach's alpha internal reliability coefficient values for subscales will be greater than .80 (Henson, 2001).

### Confirmatory Factor Analysis

Following the EFA, a confirmatory factor analysis was carried out. The model used the two-thirds sample ($n = 866$) not included in the EFA (e.g., Bates et al., 2012; Thompson, 2004; Worthington & Whittaker, 2006). The CFA analysis for the present study followed common procedures as found in Hair et al. (2013), Kline (2004), and Thompson (2004). The covariance matrix was tested for multivariate normality with evaluation for a critical ratio ($CR > 5$; e.g., Byrne, 2010; Kline, 2016). When the data failed the normality test, bootstrapping was conducted and compared to non-bootstrapped results per Kline (2016). When no statistically significant difference between the two datasets resulted, non-bootstrapped data were used (Kline, 2016). Mahalanobis distance was used to test for multivariate outliers (cf. Byrne, 2010). Byrne (2010) and Kline (2016) suggest that some non-normality may be expected in a dataset given its particular items and participants. For example, item CK_1 “I have sufficient knowledge about my teaching subject” is an item that one would expect to find a highly peaked value for in Texas community college faculty who generally have a Master’s degrees in their teaching areas (SACSCOC, 2006). Bootstrapped and non-bootstrapped data were compared, and no statistically significant differences were found between them; therefore, non-bootstrapped data are reported here (e.g., Kline, 2016; Thompson, 2004). Pattern and structure matrices were evaluated as shown in the hypotheses. Fit indices as described in the hypotheses were reviewed to determine the best-fitting model. Good model fit was achieved with the 7-factor correlated model and did not require respecification (e.g., Byrne, 2010; Kline, 2016).

The CFA model was created in IBM® SPSS AMOS version 24. The model was identified by constraining a single-factor pattern coefficient on each factor to a fixed number (e.g., “1”) or by constraining the latent factors variance to a fixed number (e.g., “1”) and by setting the path coefficient from each error term to its item to “1” (e.g., Byrne, 2010; Thompson, 2004). Pattern coefficients were evaluated for values greater than .70 (e.g., Kline, 2016; Tabachnick & Fidell, 2007). Structure coefficients were inspected to ensure that items loaded most heavily on their expected factors (Graham et al., 2003). Reliability was determined by a composite reliability greater than .7 (cf. Hair et al., 2015). Convergent validity was determined by pattern coefficient values greater than .70 (Kline, 2016) but less than .95 and an average variance extracted (AVE) greater than .50 (Bagozzi & Yi, 1988). Discriminant validity was assessed by inspecting the square root value of the AVE being greater than the individual factor correlations (Bagozzi & Yi, 1988; Hair et al., 2015).

A 7-factor correlated model was tested to determine whether the model fit the data using absolute fit statistics and indices $\chi^2$, *df*, *p*-value of $\chi^2$, RMSEA, and SRMR, as well as TLI and CFI incremental fit indices. The $\chi^2$ statistic measures the differences between the observed sample and the estimated covariance matrix—a measure of how well the data fit the theoretical model (cf. Hair et al., 2015). The assumption is that the observed covariance matrix and estimated covariance matrix will be the same (null hypotheses) and, therefore, a statistically insignificant *p*-value is expected (cf. Hair et al., 2015). However, $\chi^2$ is subject to inflation with the increase in sample size increases, the number of free parameters in the model (*df*), and the number of indicators in the model (cf. Hair et al., 2015). The RMSEA statistic is designed to help correct for issues with the $\chi^2$ statistic, is a better representation of how well the model fits the population rather than just the sample, and is well-suited for CFA with large ($n > 500$) samples (cf. Hair et al., 2015). Confidence intervals can also be constructed for RMSEA providing a range of values for a given level of confidence (95% in the present research; cf. Hair et al., 2015). The SRMR represents the average of standardized residual (error) variance with lower values indicating better fit (cf. Hair et al., 2015). The incremental fit indices provide values that suggest how well the "estimated model fits relative to some alternative baseline model" (Hair et al., 2015, p. 580), a null model or an uncorrelated model in the present research. The TLI and CFI are both improvements on the normed fit index (NFI).

The TLI is not normed and can have values below zero and above one; however, a good-fitting model will have a value close to 1 (cf. Hair et al., 2015). The CFI is a normed value, so all values that fall between 0 and 1 with values greater than 0.90 are generally associated with good-fitting models (cf. Hair et al., 2015). The CFA hypotheses are included here for the reader's convenience.

**CFA Hypotheses**

H2.1: Pattern coefficients will be greater than .70 (cf. Hair, Black, Babin, & Anderson, 2015; Kline, 2016; Tabachnick & Fidell, 2007).

H2.2: Structure coefficients will load most heavily on their respective factors (Graham et al., 2003).

H2.3: Composite reliability (CR) for each construct will be greater than .70 (cf. Hair et al., 2015)

H.2.4: Convergent validity as measured by pattern coefficients greater than .70 (Kline, 2016) and less than .95 (cf. Bagozzi & Yi, 1988) and average variance extracted (AVE) greater than 0.50 (cf. Bagozzi & Yi, 1988).

H.2.5: Discriminant validity as measured by the square root of the AVE will be greater than the individual factor correlations (cf. Bagozzi & Yi, 1988; Hair et al., 2015).

H2.6: Data from the TPACK will yield good global fit indices as measured by: TLI ≥ .95, CFI ≥ .95, RMSEA ≤ .06, SRMR ≤ .05 (cf. Schumacker & Lomax, 2016).

H2.7 Data from the TPACK will yield absolute value of residual correlations less than .10 (cf. Kline, 2016).

## Common Method Variance

Williams et al. (2010) suggested a confirmatory factor analysis (CFA) latent marker technique to test for Common Method Variance (CMV), a potential source of bias in the correlations analyzed in this study. Following suggestions from Podsakoff et al. (2003), this study used an eight-item Attitudes Toward the Color Blue (ATTCB) scale to test for CMV (Miller & Chiodo, 2008) that included four reverse-coded items. The ATTCB scale was measured on a 7-point Likert-type scale with 1 = *Strongly disagree* and 7 = *Strongly agree.* Sample items included in the scale were "I prefer blue to other colors" and "I think blue cars are ugly*"* (reverse code; Miller & Chiodo, 2008).

Following Williams et al. (2010), a series of models was tested to reveal CMV and its influence. First, a CFA model with the marker variable was tested. Second, a baseline model was tested where the seven correlations between the CMV marker method and substantive latent variables were set to 0 and the unstandardized regression weights and variances for the marker variable were fixed to the values obtained from the CFA marker model. Third, a constrained model (Method-C) was tested, where the factor loadings from the latent marker variable were constrained to be equal. Fourth, an unconstrained model (Method-U) was tested where the factor loadings from the latent marker variables were freely estimated. Finally, a restricted model (Model-R) was tested where the substantive factor covariances from Model-U were set to their values from the baseline model. Model fit indices including $\chi^2$, *df*, CFI, RMSEA, $\Delta\chi 2$, $\Delta df$, and ΔCFI were evaluated for the presence of CMV and whether they appeared to bias the relationships among the substantive variables (cf. Williams et al., 2010).

## Summary

The current research was conducted with a cross-sectional survey design to test the reliability and validity of the CC-TSML in a 2-year public college sample in Texas. The instrument selected was reviewed by an expert committee who made minor changes to ensure the instrument's face validity for use with Texas community college faculty. Participants were recruited from all 50 community college districts in Texas via email invitation to the online survey. In addition to items regarding the TPACK constructs, a CFA marker variable, ATTCB, was included to allow this data to be evaluated for CMV.

# Chapter Four – Results

This chapter provides the results for the statistical analyses conducted to test the reliability and validity of the data collected with the CC–TSML with a sample of Texas community college faculty. The chapter covers data collection and preparation prior to the sequential EFA–CFA analysis (Bates et al., 2012; Worthington & Whitaker, 2006), the EFA and CFA analyses, and the test for CMV.  The EFA and CFA analyses are covered in detail in the narrative and supported by tables where appropriate. The tests for CMV reveal whether CMV is present and whether it biased the correlations between factors.

## Data Collection

Data were collected in January and February 2018 as detailed in Chapter 3 and downloaded on Wednesday, February 7, 2018. Of the 25,000 initial invitations, 3.8% were not deliverable (*n* = 951). Of the 24,049 delivered invitations, 9.0% clicked the link to view the survey (*n* = 2,173). The screening questions were answered by 86.0% of those who clicked the survey link (*n* = 1,868). Of the 1,868 individuals who clicked the survey link, 93.7% consented to participate (*n* = 1,750). Of those who consented to participate, 91.3% completed the survey (*n* = 1,597) while 8.7% (*n* = 153) abandoned the survey after consenting.

## Data Cleaning

Prior to cleaning or analyzing the data, four negatively worded items in ATTCB were reverse coded to allow for analysis with the positively worded items. The range of values for all variables was inspected and no values fell outside expected ranges. To ensure that only faculty participated in the study, a crosstab check of the employment status screening question and the faculty status demographic question was conducted, which revealed four cases for deletion. Cases where straight-lining in the ATTCB scale was detected and the respondent failed the survey expected completion time window (4 minutes $\leq$ time $\geq$ 14 minutes) were identified ($n$ = 294) and removed, leaving 1,299 cases for analysis.

## Study Participants

The Select Cases feature in IBM® SPSS was used to randomly select 25,000 email addresses for inclusion in the initial study email invitation from the database of Texas community college faculty email addresses.  After cleaning, the study sample consisted of 1,299 full- and part-time faculty from 2-year public colleges in Texas. Participants were expected to be similar to the general population of faculty at 2-year public colleges in Texas given that they were randomly selected from all 50 of the community college districts in Texas (THECB, 2017).  However, an analysis of the data show that the sample in our CC-TSML study is both statistically and practically significantly different from the population (see Table 7).

When comparing the sample from the present research to the population, we find that the sample is statistically different from the population of Texas community college faculty at the *p* < .001 level in every category except part-time – gender which is statistically significant at the *p* < .01 level. When examining the practical significance of

Table 7

*Comparison of CC-TSML study sample with Fall 2015 Texas community college population*

| | CC-TSML Survey Data (*n* = 1,299) | | 2015 THECB Population Data (*n* = 43,234) | | Population | |
|---|---|---|---|---|---|---|
| Faculty | Total | % total | Total | % total | *p*-value | Cramer's *V* |
| *2-year public college faculty* | | | | | <.001 | .529 |
| Full-time faculty | 778 | 59.89% | 15,005 | 34.71% | | |
| Part-time faculty | 521 | 40.11% | 28,229 | 65.29% | | |
| *Total faculty - Gender* | | | | | < .001 | .193 |
| Female | 825 | 63.51% | 23,305 | 53.90% | | |
| Male | 474 | 36.49% | 19,929 | 46.10% | | |
| *Total faculty - Ethnicity* | | | | | < .001 | .139 |
| African American | 74 | 5.70% | 5,350 | 12.37% | | |
| Asian | 24 | 1.85% | 2,106 | 4.87% | | |
| Hispanic | 143 | 11.01% | 6,224 | 14.40% | | |
| International | 10 | 0.77% | 119 | 0.28% | | |
| Other | 56 | 4.31% | 1,942 | 4.49% | | |
| White | 992 | 76.37% | 27,493 | 63.59% | | |
| *Full-time faculty - Gender* | | | | | < .001 | .265 |
| Female | 509 | 65.42% | 7,839 | 52.24% | | |
| Male | 269 | 34.58% | 7,166 | 47.76% | | |
| *Full-time faculty - Ethnicity* | | | | | < .001 | .124 |
| African American | 39 | 5.01% | 1,356 | 9.04% | | |
| Asian | 17 | 2.19% | 670 | 4.47% | | |
| Hispanic | 94 | 12.08% | 2,512 | 16.74% | | |
| International | 6 | 0.77% | 24 | 0.16% | | |
| Other | 27 | 3.47% | 605 | 4.03% | | |
| White | 595 | 76.48% | 9,838 | 65.56% | | |

|  | CC-TSML Survey Data (*n* = 1,299) |  | 2015 THECB Population Data (*n* = 43,234) |  | Population |  |
|---|---|---|---|---|---|---|
| Faculty | Total | % total | Total | % total | *p*-value | Cramer's *V* |
| *Part-time faculty - Gender* |  |  |  |  | .007 | .118 |
| Female | 316 | 60.65% | 15,466 | 54.79% |  |  |
| Male | 205 | 39.35% | 12,763 | 45.21% |  |  |
| *Part-time faculty - Ethnicity* |  |  |  |  | < .001 | .152 |
| African American | 35 | 6.72% | 3,994 | 14.15% |  |  |
| Asian | 7 | 1.34% | 1,436 | 5.09% |  |  |
| Hispanic | 49 | 9.40% | 3,712 | 13.15% |  |  |
| International | 4 | 0.77% | 95 | 0.34% |  |  |
| Other | 29 | 5.57% | 1,337 | 4.74% |  |  |
| White | 397 | 76.20% | 17,655 | 62.54% |  |  |

*Note*. CC-TSML = Community College TPACK Survey for Meaningful Learning. 2015 THECB Population Data adapted from “Texas Higher Education Accountability System” by THECB, 2017.

these differences by calculating Cramer’s *V* and referring to Cohen’s (1988) suggestions on effect sizes (e.g., .2 = small, .5 = medium, and .8 = large), it is apparent that the differences in study sample to the population is both statistically signification ($p < .001$) and practically significant with small to large effects, depending on the demographic characteristics. Small effects (Cohen, 1988) are evident in CC-TSML survey sample differences to the population for total faculty – ethnicity, full-time faculty – ethnicity, and part-time faculty – gender. Small to moderate effect sizes are present for total faculty – gender and part-time faculty-ethnicity (Cohen, 1988). Moderate effect sizes are seen for full-time faculty – gender and a large effect size is seen in total faculty by employment status (e.g., full-time vs. part-time) (Cohen, 1988).

## Exploratory Factor Analysis

Using the IBM© SPSS “Select Cases” function, the data were split into one-third (*n* = 433) for EFA and two-thirds (*n* = 866) for CFA (Bates et al., 2012; Worthington & Whitaker, 2006). The EFA used ML estimation, oblique promax rotation, and an *a priori* factor structure of seven TPACK factors. Three analytic revisions were necessary to achieve minimum thresholds on pattern matrix loadings. All three analytic revisions demonstrated (a) sampling adequacy as shown by their KMO, (b) sufficiently correlated data as evidenced by a statistically significant Bartlett’s Test of Sphericity ($p < .001$), and (c) rotation convergence in seven iterations. During the three analytical iterations, no items showed significant cross-loading and all structure coefficients demonstrated that items loaded most heavily on their respective factors.

In the initial EFA, all items for each TPACK construct in the CC–TSML were included. A KMO = .911 indicated sampling adequacy. Convergent validity was assessed by reviewing the pattern matrix for factor loadings greater than .5 and cross-loading of .32 or less (e.g., Costello & Osborne, 2005). The initial pattern matrix indicated one item, PK_5 (“I am able to plan group activities for my student.”), had a pattern coefficient of .427, below the study threshold and marking it for exclusion from further analysis. In the second EFA iteration, the item PK_5 was removed providing a KMO = .912. The pattern matrix revealed one item for removal: PK_6 (“I am able to guide my students to engage in effective discussion during group work.”) had a pattern coefficient below the study threshold (PK_6 = .497). The third iteration of the EFA excluded items PK_5 and PK_6 and produced a KMO = .910. The pattern and structure matrices provided evidence of convergent validity as all items had a pattern coefficient greater than .5 with no evident

Table 8

*EFA pattern and structure coefficients for the CC-TSML*

| | TK | | TPACK | | PK | | TPK | | PCK | | CK | | TCK | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC–TSML Subscale | P | S | P | S | P | S | P | S | P | S | P | S | P | S | *$h^2$* |
| *TK* | | | | | | | | | | | | | | | |
| TK_1 | **.603** | **.566** | .033 | .314 | .028 | .223 | -.107 | .335 | -.027 | .010 | .061 | .149 | -.006 | .318 | .329 |
| TK_2 | **.751** | **.660** | -.044 | .313 | -.023 | .190 | -.013 | .394 | -.026 | -.016 | -.013 | .071 | -.079 | .317 | .447 |
| TK_3 | **.702** | **.831** | .015 | .526 | -.036 | .315 | .139 | .647 | .035 | .065 | -.011 | .134 | .069 | .575 | .710 |
| TK_4 | **.643** | **.776** | -.017 | .486 | -.050 | .262 | .101 | .602 | -.013 | .011 | -.046 | .084 | .170 | .579 | .633 |
| TK_5 | **.826** | **.785** | -.016 | .422 | -.056 | .224 | -.069 | .486 | -.002 | .017 | -.007 | .101 | .061 | .472 | .623 |
| TK_6 | **.713** | **.705** | .064 | .412 | .168 | .365 | -.060 | .461 | -.003 | .047 | -.035 | .127 | -.100 | .372 | .521 |
| TK_7 | **.732** | **.694** | -.003 | .368 | .007 | .257 | .030 | .454 | .007 | .030 | .019 | .125 | -.104 | .354 | .488 |
| *TPACK* | | | | | | | | | | | | | | | |
| TPACK_1 | .044 | .482 | **.845** | **.836** | -.062 | .204 | .051 | .529 | .005 | .019 | .020 | .083 | -.085 | .455 | .705 |
| TPACK_2 | -.050 | .474 | **.913** | **.900** | -.069 | .211 | .021 | .555 | -.014 | .010 | .033 | .100 | .032 | .534 | .816 |
| TPACK_3 | .008 | .502 | **.915** | **.900** | .000 | .259 | .029 | .567 | .004 | .031 | -.008 | .084 | -.062 | .499 | .813 |
| TPACK_4 | .023 | .513 | **.887** | **.893** | .055 | .296 | -.099 | .544 | -.014 | .034 | -.003 | .113 | .069 | .555 | .804 |
| TPACK_5 | -.003 | .514 | **.821** | **.876** | .037 | .290 | .042 | .592 | .009 | .043 | -.052 | .068 | .040 | .554 | .773 |
| *PK* | | | | | | | | | | | | | | | |
| PK_1 | .116 | .307 | .039 | .228 | **.612** | **.682** | -.116 | .298 | .061 | .235 | .126 | .402 | .006 | .270 | .494 |
| PK_2 | .018 | .282 | -.023 | .206 | **.867** | **.839** | -.076 | .339 | -.021 | .190 | .012 | .369 | .021 | .277 | .708 |
| PK_3 | -.060 | .292 | -.050 | .236 | **.820** | **.829** | .090 | .425 | -.020 | .179 | -.018 | .337 | .045 | .327 | .694 |
| PK_4 | -.014 | .308 | -.005 | .255 | **.768** | **.782** | .159 | .436 | -.004 | .170 | -.050 | .282 | -.086 | .272 | .626 |

| | TK | | TPACK | | PK | | TPK | | PCK | | CK | | TCK | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC–TSML Subscale | P | S | P | S | P | S | P | S | P | S | P | S | P | S | $h^2$ |
| *TPK* | | | | | | | | | | | | | | | |
| TPK_1 | .050 | .548 | .040 | .522 | -.031 | .335 | **.515** | **.720** | -.008 | .042 | .040 | .173 | .231 | .625 | .559 |
| TPK_2 | .027 | .577 | .018 | .542 | .060 | .424 | **.611** | **.792** | -.056 | .013 | .035 | .198 | .181 | .639 | .656 |
| TPK_3 | -.067 | .526 | -.008 | .517 | .002 | .379 | **.934** | **.855** | -.031 | .000 | -.021 | .115 | -.037 | .537 | .738 |
| TPK_4 | -.024 | .584 | .057 | .579 | .058 | .465 | **.961** | **.910** | .041 | .081 | -.011 | .158 | -.146 | .539 | .843 |
| TPK_5 | .187 | .658 | .026 | .560 | -.024 | .394 | **.664** | **.818** | .042 | .083 | .036 | .186 | .024 | .597 | .696 |
| *PCK* | | | | | | | | | | | | | | | |
| PCK_1 | -.041 | -.017 | .012 | .005 | .002 | .182 | -.001 | .001 | **.834** | **.830** | -.004 | .149 | -.023 | .046 | .692 |
| PCK_2 | .010 | .058 | -.010 | .046 | .038 | .259 | .005 | .066 | **.925** | **.931** | -.022 | .178 | .008 | .118 | .868 |
| PCK_3 | .000 | .027 | -.012 | .021 | -.042 | .200 | -.006 | .028 | **.955** | **.951** | .021 | .192 | .023 | .101 | .906 |
| *CK* | | | | | | | | | | | | | | | |
| CK_1 | .000 | .121 | -.068 | .044 | -.011 | .336 | .078 | .146 | -.013 | .141 | **.815** | **.807** | -.034 | .139 | .656 |
| CK_2 | .025 | .153 | .010 | .099 | -.057 | .347 | -.021 | .142 | -.005 | .167 | **.942** | **.920** | .009 | .187 | .849 |
| CK_3 | -.047 | .128 | .080 | .144 | .166 | .396 | -.050 | .157 | .017 | .166 | **.550** | **.621** | .025 | .184 | .413 |
| *TCK* | | | | | | | | | | | | | | | |
| TCK_1 | -.019 | .357 | -.033 | .357 | -.121 | .130 | .001 | .407 | -.002 | .045 | .010 | .102 | **.738** | **.667** | .459 |
| TCK_2 | -.052 | .422 | -.015 | .430 | .106 | .347 | -.054 | .494 | .003 | .108 | -.002 | .190 | **.811** | **.774** | .609 |
| TCK_3 | .021 | .488 | .103 | .520 | .045 | .313 | .004 | .546 | .019 | .098 | -.031 | .143 | **.667** | **.754** | .581 |

Note. $h^2$ = communalities. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge. P = pattern coefficient. S = structure coefficient.

cross-loading and all items loading most heavily on their respective factors (see Table 8). Cronbach's alpha for all subscales was greater than .80 except TCK = .776. The total variance explained was 65.688%.  The eigenvalue for the first factor not retained is .805 (see Table 9).

Table 9

*Internal reliability and variance explained for the CC–TSML subscales*

| | TK | TPACK | PK | TPK | PCK | CK | TCK |
|---|---|---|---|---|---|---|---|
| Cronbach's Alpha | .869 | .945 | .859 | .908 | .928 | .814 | .776 |
| Eigenvalues | 10.413 | 3.473 | 2.221 | 1.919 | 1.537 | 1.374 | 1.042 |
| % Var Extracted | 33.089 | 9.611 | 7.509 | 4.983 | 4.622 | 3.251 | 2.622 |
| Cumulative Var Extracted | 33.089 | 42.700 | 50.209 | 55.192 | 59.814 | 63.065 | 65.687 |

**Hypotheses Outcomes**

The EFA hypothesis H1.1 is partially supported. The removal of items PK_5 and PK_6 was necessary to bring all pattern coefficients greater than .50. No items showed evidence of significant cross-loading. Hypothesis H1.2 is supported as all structure coefficients loaded most heavily on their expected factors. Hypothesis H1.3 is partially supported. All Cronbach's alpha reliability coefficient values for the subscales TK, TPACK, PK, PCK, TPK, and CK were greater than .80 with the exception of TCK = .776.

Table 10

*EFA hypotheses outcomes*

| EFA Hypotheses | | Supported | Notes |
|---|---|---|---|
| H1.1 | Pattern coefficients will be greater than .50 with cross-loading of less than .32 | Partial | Removed PK_5 and PK_6 |

| EFA Hypotheses | | Supported | Notes |
|---|---|---|---|
| H1.2 | Structure coefficients will load most heavily on their respective factors | Yes | |
| H1.3 | Cronbach's alpha internal reliability coefficient values for subscales will be greater than .80 | Partial | TCK = .776 |

## Confirmatory Factor Analysis

During the CFA using the 866 cases left after the CFA, a 7-factor correlated model was tested for global and local model fit. Global fit indices included RMSEA, SRMR, TLI and CFI. Local fit was evaluated using the absolute value of residual correlations. For the CC-TSML subscales, pattern coefficients, structure coefficients, composite reliability, convergent reliability and discriminant validity were tested according to the CFA hypotheses.

### Model Fit and the Absolute Value of Residual Correlations

Using IBM® SPSS AMOS version 24, a 7-factor correlated model was tested to determine whether the model fit the data using absolute fit statistics and indices. Figure 8 shows the 7-factor correlated model with its items. Table 11 shows the fit indices for the 7-factor correlated model.

Table 11

*CFA model fit indices for the CC-TSML 7-factor correlated model*

| | | | | TLI | CFI | RMSEA | | | SRMR |
|---|---|---|---|---|---|---|---|---|---|
| Model | $\chi^2$ | *df* | *p* | ≥ .95 | ≥ .95 | ≤ .06 | LO 90 | HI 90 | ≤ .05 |
| 7-Factor Correlated | 1352.52 | 384 | <.001 | .932 | .940 | .054 | .051 | .057 | .039 |

*Note*. CC-TSML = Community College TPACK Survey for Meaningful Learning.

The 7-factor model appeared to fail the $\chi^2$ absolute fit statistic with a statistically significant *p*-value; however, the $\chi^2$ statistic and *p*-value may be inflated by more complex models and larger samples sizes. The 7-factor model exceeded the threshold for RMSEA including across the 90% confidence interval (cf. Hair et al., 2015; Kline, 2016). The 7-factor model exceeded the SRMR threshold (Kline, 2016). Given the issues with $\chi^2$

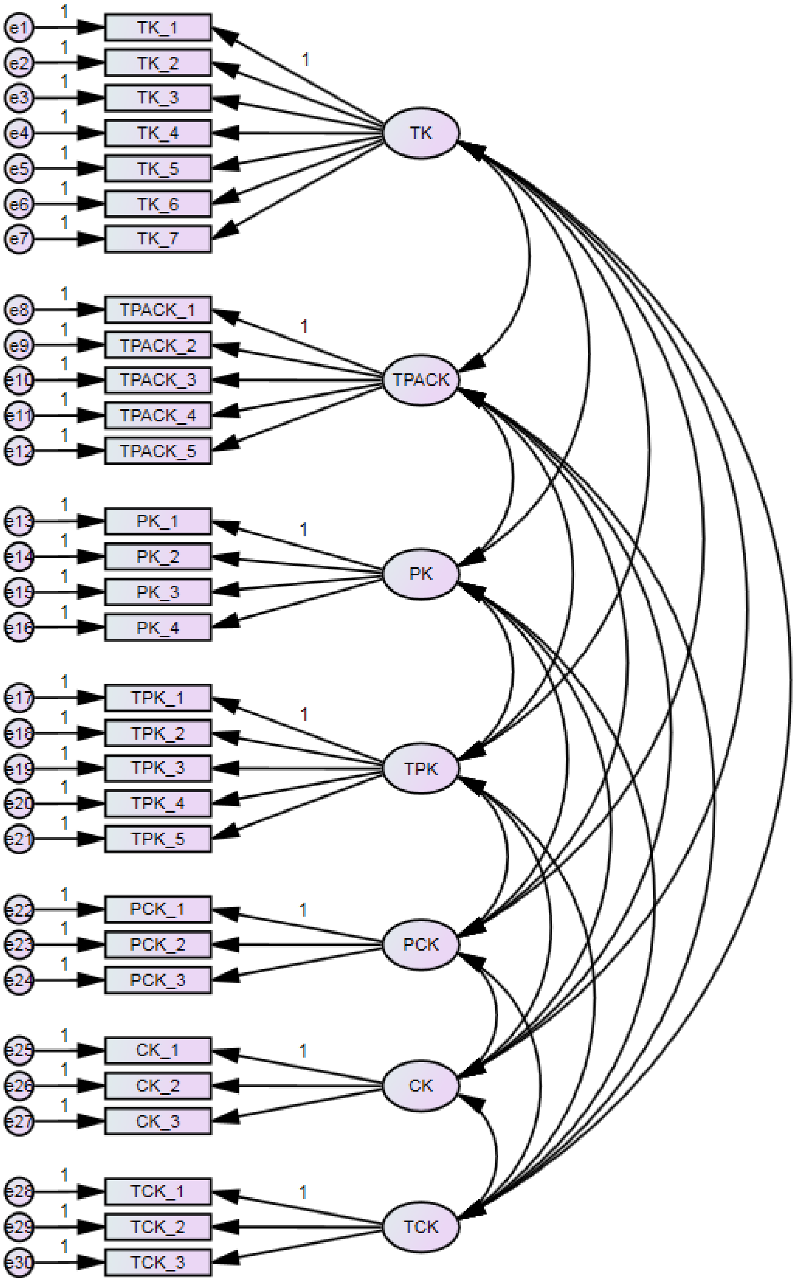

*Figure 8*. CC–TSML 7-factor correlated model.
*Note*. CC-TSML = Community College TPACK Survey for Meaningful Learning.

when used with complex models and large sample sizes, such as the 7-factor correlated model, as well as the model exceeding thresholds for RMSEA and SRMR, the 7-factor correlated model demonstrated adequate absolute fit, thereby supporting a null hypotheses and signifying that the observed sample and estimated covariance matrix were not statistically significantly different.

When the 7-factor correlated model was measured against the comparative fit indices, it seemed to fall short of the thresholds; however, Hair et al. (2015) discussed guidelines for reporting and interpreting multiple fit indices. Using simulation research that included models of varying complexity, different sample sizes, and model specification errors, Hair et al. (2015) provided alternative fit guidelines. Using these guidelines for sample sizes greater than 250 and observed items greater than 30, the thresholds for TLI and CFI fall to .90 (Hair et al., 2015). When adjusted, the 7-factor correlated model met the thresholds for absolute fit indices (RMSEA and SRMR) and comparative fit indices (TLI and CFI), indicating a good model fit and signifying that the observed sample data and estimated covariance matrix were equal.

The absolute value of residual correlations, a measure of error variance between the observed model and the estimated model, were measured by calculating the differences between the observed residuals and the implied residuals across all TPACK items. Nine pairs of items demonstrated residual correlations greater than the absolute value of .10: CK_3 to PK_1 (.212), CK_2 to PK_1 (.141), TPK_5 to TPACK_5 (.105), TPK_5 to TK_6 (.115), TPK_5 to TK_3 (.136), TPACK_4 to TK_2 (-.106), TPACK_3 to TK_2 (1.119), TK_7 to TK_6 (.142), and TK_6 to TK_4 (-.107) (Kline, 2016).

After identifying the absolute correlation residual pairs and looking for patterns in the absolute value of residual correlations as recommended by Kline (2016), it is apparent a number of TK items were involved (TK_2, TK_3, TK_4, TK_6, and TK_7), several of which also displayed low factor loadings, which may indicate a need to further refine the model.  Byrne (2010) also suggests reviewing the modification indices for opportunities to improve model fit.  Both the absolute value of residual correlations and modification indices from the 7-factor correlated mode were considered; error terms were discovered for several TK items which could be correlated to see whether a better fitting model could be found.

The 7-factor model was tested with errors correlated between items TK_5 and TK_6 (Model 1), items TK_4 and TK_6 (Model 2), items TK_3 and TK_4 (Model 3), as well as items TK_3 and TK_6 (Model 4). In each case, there was minimal change (down to eight pairs from nine). Moreover, in Model 3, the TK item pattern coefficients degenerated even though in Model 4, the TK subscale was able to achieve discriminant validity from the TCK subscale. The local fit issue found with the absolute value of residual correlations was not practically improved by correlating the error terms. Items TK_2, TK_3, TK_4, and TK_6 still produced absolute value of residual correlations greater than .10.   There is no justification for correlating these error terms in the existing literature (e.g., Chai et al., 2013; Koh et al., 2014). Adequate model fit was achieved with 7-factor correlated model, the model expected and justified in literature (e.g., Mishra & Koehler, 2006; Koh et al., 2014). Therefore, only the 7-factor correlated model is reported in Table 11.

## Reliability and Validity

The CFA was conducted using the 866 cases not used during the EFA process (cf. Worthington & Whittaker, 2006). The CFA was conducted using IBM© SPSS AMOS version 24. The CFA used ML estimation using covariances as input and as the analysis matrix. The data were found to be multivariate non-normal with leptokurtic values for some CK items (CK_3 = 8.150, CK_1 = 17.328) with kurtosis ≥ 7 as an indication of non-normality (Byrne, 2010). The critical ratio was calculated as 152.22, reaffirming multivariate non-normality (e.g., Byrne, 2010; Kline, 2016; Thompson, 2004). Multivariate outliers were found using the $D^2$ test (e.g., Kline, 2016). Byrne (2010) and Kline (2016) indicated that some non-normality may be expected in a dataset given its particular items and participants and that bootstrapping is an adequate remedy for handling both non-normality and outliers. Bootstrapped and non-bootstrapped data were compared with no statistically significant differences found; therefore, non-bootstrapped data are reported here (e.g., Kline, 2016; Thompson, 2004). The CC–TSML subscales for each TPACK construct were tested according to the CFA hypotheses. The CFA hypotheses focus on pattern and structure coefficients (H2.1 and H2.2), composite reliability (H2.3), convergent reliability (H2.4), discriminant validity (H2.5), global fit indices (H2.6), and the absolute value of residual correlations (H2.7).

**Content Knowledge (CK).** This CC–TSML subscale consisted of three items with pattern coefficients of .707 to .893 and structure coefficients loading most heavily on the CK factor (see Table 12) (Graham et al., 2003; Hair et al., 2015). Composite

Table 12

*CFA pattern and structure coefficients*

|  | TK |  | TPACK |  | PK |  | TPK |  | PCK |  | CK |  | TCK |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construct Variable | P | S | P | S | P | S | P | S | P | S | P | S | P | S |
| *TK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TK_1 | .563 | .563 |  | .301 |  | .255 |  | .369 |  | -.003 |  | .164 |  | .377 |
| TK_2 | .596 | .596 |  | .318 |  | .269 |  | .390 |  | -.004 |  | .174 |  | .398 |
| TK_3 | .831 | .831 |  | .444 |  | .375 |  | .543 |  | -.005 |  | .242 |  | .556 |
| TK_4 | 729 | .729 |  | .389 |  | .329 |  | .477 |  | -.004 |  | .212 |  | .488 |
| TK_5 | .764 | .764 |  | .408 |  | .345 |  | .500 |  | -.005 |  | .222 |  | .511 |
| TK_6 | .663 | .663 |  | .354 |  | .300 |  | .434 |  | -.004 |  | .193 |  | .444 |
| TK_7 | .670 | .670 |  | .358 |  | .303 |  | .439 |  | -.004 |  | .195 |  | .448 |
| *TPACK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TPACK_1 |  | .437 | .819 | .819 |  | .253 |  | .513 |  | -.008 |  | .149 |  | .490 |
| TPACK_2 |  | .466 | .872 | .872 |  | .270 |  | .547 |  | -.009 |  | .159 |  | .522 |
| TPACK_3 |  | .477 | .894 | .894 |  | .276 |  | .561 |  | -.009 |  | .163 |  | .535 |
| TPACK_4 |  | .480 | .899 | .899 |  | .278 |  | .563 |  | -.009 |  | .164 |  | .538 |
| TPACK_5 |  | .444 | .832 | .832 |  | .257 |  | .522 |  | -.008 |  | .152 |  | .498 |
| *PK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| PK_1 |  | .290 |  | .198 | .641 | .641 |  | .341 |  | .136 |  | .310 |  | .237 |
| PK_2 |  | .377 |  | .258 | .834 | .834 |  | .444 |  | .177 |  | .403 |  | .308 |
| PK_3 |  | .374 |  | .256 | .829 | .829 |  | .441 |  | .176 |  | .400 |  | .306 |
| PK_4 |  | .386 |  | .264 | .854 | .854 |  | .454 |  | .182 |  | .412 |  | .315 |
| *TPK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TPK_1 |  | .477 |  | .457 |  | .388 | .729 | .729 |  | -.002 |  | .197 |  | .563 |
| TPK_2 |  | .515 |  | .493 |  | .418 | .786 | .786 |  | -.002 |  | .212 |  | .607 |
| TPK_3 |  | .530 |  | .508 |  | .431 | .810 | .810 |  | -.002 |  | .219 |  | .625 |

|  | TK |  | TPACK |  | PK |  | TPK |  | PCK |  | CK |  | TCK |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Construct Variable | P | S | P | S | P | S | P | S | P | S | P | S | P | S |
| TPK_4 |  | .552 |  | .529 |  | .449 | .843 | .843 |  | -.003 |  | .228 |  | .651 |
| TPK_5 |  | .481 |  | .461 |  | .391 | .735 | .735 |  | -.002 |  | .198 |  | .568 |
| *PCK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| PCK_1 |  | -.005 |  | -.008 |  | .173 |  | -.002 | .814 | .814 |  | .157 |  | .036 |
| PCK_2 |  | -.005 |  | -.009 |  | .196 |  | -.003 | .920 | .920 |  | .178 |  | .040 |
| PCK_3 |  | -.005 |  | -.009 |  | .186 |  | -.003 | .876 | .876 |  | .169 |  | .038 |
| *CK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CK_1 |  | .206 |  | .129 |  | .341 |  | .191 |  | .136 | .707 | .707 |  | .232 |
| CK_2 |  | .260 |  | .163 |  | .432 |  | .241 |  | .173 | .893 | .893 |  | .294 |
| CK_3 |  | .228 |  | .143 |  | .377 |  | .211 |  | .151 | .781 | .781 |  | .257 |
| *TCK* |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| TCK_1 |  | .422 |  | .378 |  | .233 |  | .487 |  | .028 |  | .207 | .631 | .631 |
| TCK_2 |  | .507 |  | .454 |  | .280 |  | .586 |  | .033 |  | .249 | .758 | .758 |
| TCK_3 |  | .542 |  | .485 |  | .299 |  | .626 |  | .035 |  | .267 | .811 | .811 |

*Note.* TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

reliability is .838, meeting the Hair et al. (2015) threshold test (> .70). This subscale demonstrates convergent reliability by meeting the thresholds of pattern coefficients ≥ .70 (Kline, 2016) and < .95 (Bagozzi & Yi, 1988) and AVE > .50 (Bagozzi & Yi, 1988). Discriminant validity is measured by determining whether the square root of the subscale AVE is greater than the individual factor correlations (cf. Bagozzi & Yi, 1988; Hair et al., 2015). The square root of AVE for CK = .797, greater than all other individual factor correlations, demonstrated discriminant validity for this subscale. See Table 13 for implied factor correlations, AVE, and composite reliability for all CC–TSML factors.

Table 13

*CC–TSML implied factor correlations, AVE, and composite reliability*

| CC–TSML Subscale | TK | TPACK | PK | TPK | PCK | CK | TCK |
|---|---|---|---|---|---|---|---|
| TK | **.660** | | | | | | |
| TPACK | .534 | **.864** | | | | | |
| PK | .452 | .309 | **.794** | | | | |
| TPK | .654 | .627 | .532 | **.782** | | | |
| PCK | -.006* | -.010* | .213 | -.003* | **.871** | | |
| CK | .291 | .183 | .483 | .270 | .193 | **.797** | |
| TCK | .669 | .598 | .369 | .772 | .044* | .329 | **.737** |
| *CR* | .860 | .936 | .741 | .887 | .904 | .838 | .779 |
| *AVE* | .436 | .746 | .631 | .611 | .759 | .636 | .543 |

*Note*. Square root of AVE on diagonal; p < .001. **p* > .3. CC-TSML = Community College TPACK Survey for Meaningful Learning. CR = composite reliability. AVE = average variance extracted. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

**Pedagogical Knowledge (PK).** This CC–TSML subscale was initially a six-item scale. Items PK_5 and PK_6 were removed during the EFA phase as they failed to meet the factor-loading threshold (> .5; Costello & Osborne, 2005). Pattern coefficients for the revised four-item subscale range from .641–.854; structure coefficients showed the items loaded together on a single factor (Graham et al., 2003; Hair et al., 2015). Composite reliability was adequate at .741 (Hair et al., 2015). The PK subscale had some convergent reliability issues. Item PK_1 (see Table 13) had a pattern coefficient of only .641, less than the threshold established by Kline (≥ .70; 2016); however, the pattern coefficient was less than .95 (Bagozzi & Yi, 1988) and AVE = .631, higher than the minimum threshold of .50 established by Bagozzi and Yi (1988). The square root of AVE for PK = .794, greater than all other individual factor correlations, demonstrated discriminant validity for this subscale (see Table 13).

**Pedagogical Content Knowledge (PCK).** This CC–TSML subscale produced pattern coefficients for the three-item PCK subscale ranging from .814 to .920 (cf. Hair et al., 2015). Structure coefficients show that the PCK items load most heavily together on a single factor (cf. Graham et al., 2003). See Table 21 for pattern coefficient details. Composite reliability is achieved as demonstrated with a CR = .904, well above the .70 threshold recommended by Hair et al. (2015). The PCK subscale demonstrates convergent validity with all pattern coefficients greater than .70 (Kline, 2016) and less than .95 (Bagozzi & Yi, 1988) and an AVE = .759, greater than the .50 threshold recommended by Bagozzi and Yi (1988). Discriminant validity for the PCK subscale is demonstrated by its square root of AVE being greater than its correlation to all other factors (see Table 13).

**Technological Content Knowledge (TCK).** The CC–TSML three-item TCK subscale produced pattern coefficients ranging from .631 to .811 (cf. Hair et al., 2015). Structure coefficients showed that all items loaded most heavily on a single factor representing the construct (Graham et al., 2003; see Table 12). Composite reliability of this subscale was calculated as .779, above the .70 Hair et al. (2015) threshold. The TCK subscale showed some convergent validity issues with one item producing a pattern coefficient of .631, less than the threshold  recommended by Kline (2016); however, the pattern coefficients were below .95 (Bagozzi & Yi, 1988) and AVE = .543 (Bagozzi & Yi, 1988). This subscale also showed discriminant validity issues with a square root of AVE = .737 but a correlation with TPK = .772, violating the recommendation of Hair et al. (2015). Factor correlations for all subscales are shown in Table 13.

**Technological Pedagogical Knowledge (TPK).** Pattern coefficients for the five-item TPK subscale of the CC–TSML ranged from .729 to .843 (cf. Hair et al., 2015). Structure coefficients (see Table 12) indicated items loaded most heavily on a single factor (cf. Graham et al., 2003). Composite reliability was demonstrated with CR = .887 (Hair et al., 2015). Convergent validity for the TPK subscale was shown with all pattern coefficients greater than .70 (Kline, 2016) and less than .95 (Bagozzi & Yi, 1988) with an AVE = .611 (Bagozzi & Yi, 1988). Discriminant validity of the TPK subscale was shown by the square root of AVE = .782, which was greater than all the individual factor correlations (cf. Bagozzi & Yi, 1988; Hair et al., 2015; see Table 13).

**Technological Pedagogical Content Knowledge (TPACK).** The CC–TSML five-item TPACK subscale pattern coefficients ranged from 0.819 to 0.899 (see Table 12; Hair et al., 2015). Composite reliability was demonstrated with CR = 0.936 (Hair et al., 2015). Convergent validity for the TPACK subscale was demonstrated with all item pattern coefficients greater than 0.70 (Kline, 2016) and less than 0.95 (Bagozzi & Yi, 1988) with an AVE = 0.746 (Bagozzi & Yi, 1988). Discriminant validity for the TPACK subscale was shown by the square root of AVE = 0.864, which was greater than its correlations with any other factor (cf. Bagozzi & Yi, 1988; Hair et al., 2015). See Table 13 for all TPACK factor correlations.

### Means, Standard Deviations, and Observed Correlations

In order to compare means, standard deviation, and observed correlations to the exiting literature, scale scores were created for each construct using the 866 cases from the CFA. Means and standard deviation of the present study are shown in Table 14. An unpaired *t*-test was conducted and Cohen's *d* calculated to determine if the differences in the means and standard deviations between Koh et al. (2014), a study of PK-16 faculty in Singapore participating in a professional development program related to technology, and

Table 14

*Comparison of means and SDs with Koh et al., 2014*

| | Koh et al., 2014 *n* = 354 | | CC-TSML, 2018 *n* = 866* | | Independent sample *t*-test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Scale | *M* | *SD* | *M* | *SD* | *p* (2-tailed) | Δ *M* | *SE* | *t* | *df* | Cohen's *d* |
| TK | 5.17 | 0.98 | 5.09 | 1.13 | .2443 | .08 | .07 | 1.16 | 1218 | .08 |
| TPACK | 4.86 | 1.13 | 5.39 | 1.33 | < .0001 | .53 | .08 | 6.59 | 1218 | .43 |
| PK | 5.56 | 0.77 | 5.92 | 0.80 | < .0001 | .36 | .05 | 7.21 | 1218 | .46 |
| TPK | 5.17 | 0.98 | 5.63 | 0.99 | < .0001 | .46 | .06 | 7.39 | 1218 | .47 |
| PCK | 5.43 | 1.05 | 5.89 | 1.22 | < .0001 | .46 | .07 | 6.22 | 1218 | .40 |
| CK | 5.84 | 0.93 | 6.52 | 0.61 | < .0001 | .68 | .05 | 15.02 | 1218 | .86 |
| TCK | 5.20 | 1.09 | 5.82 | 1.03 | < .0001 | .62 | .07 | 9.38 | 1218 | .58 |

*Note*. *= data changed to 2 decimal places to match data from Koh et al. (2014). Cohen's $d = (M_2 - M_1)/\sqrt{((SD_1^2 + SD_2^2)/2)}$. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

the present study of the CC-TSML were statistically and practically significant (Cohen, 1988). Results are shown in Table 14. All differences were both statistically ($p < .001$) and practically significant between the Koh et al. (2014) data and the present study with the exception of the TK construct.

Next, an unpaired *t*-test and Cohen's *d* calculations were performed with the data from the CC-TSML and Chukwuemeka and Iscioglu (2016) studies (see Table 15). Chukwuemeka and Iscioglu (2016) is the only published study using higher education faculty that uses a closely related instrument (e.g., Koh et al., 2013) and provides means and standard deviations. Differences between the two samples of higher education faculty were statistically and practically insignificant for the CK, PCK, TCK, and TPK constructs. Differences between these faculty groups on the TK construct were

Table 15

*Comparison of means and SDs with Chukwuemeka & Iscioglu, 2016*

| | Chukwuemeka & Iscioglu (2016) *n* = 53 | | CC-TSML, 2018 *n* = 866* | | Independent sample *t*-test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Scale | *M* | *SD* | *M* | *SD* | *p* (2-tailed) | Δ *M* | *SE* | *t* | *df* | Cohen's *d* |
| TK | 5.56 | 1.05 | 5.09 | 1.13 | .0058 | .47 | .17 | 2.77 | 917 | .43 |
| TPACK | 5.91 | 0.84 | 5.39 | 1.33 | .0050 | .52 | .19 | 2.81 | 917 | .47 |
| PK | 6.47 | 0.56 | 5.92 | 0.80 | .0001 | .55 | .11 | 4.93 | 917 | .80 |
| TPK | 5.80 | 0.97 | 5.63 | 0.99 | .2247 | .17 | .14 | 1.21 | 917 | .17 |
| PCK | 5.57 | 1.28 | 5.89 | 1.22 | .0649 | .32 | .17 | 1.85 | 917 | .26 |
| CK | 6.55 | 0.69 | 6.52 | 0.61 | .7303 | .03 | .09 | .34 | 917 | .05 |
| TCK | 5.86 | 0.93 | 5.82 | 1.03 | .7783 | .04 | .15 | .28 | 917 | .04 |

*Note.* *= data changed to 2 decimal places to match data from Chukwuemeka & Iscioglu (2016). Cohen's $d = (M_2 - M_1)/\sqrt{((SD_1^2 + SD_2^2)/2)}$. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

statistically and practically significant ($p < .01$, $d = .43$) with a medium effect size according to Cohen (1988). Difference between the two higher education faculty groups on the TPACK construct were both statistically and practically significant at the ($p \leq .005$, $d = .47$) showing medium effect sizes (Cohen, 1988). Differences in the PK construct were statistically and practically significant ($p < .0001$, $d = .8$) that Cohen (1988) would have deemed a large effect size.

Finally, an unpaired *t*-test with Cohen's *d* was performed for the data from the Koh et al. (2014) and Chukwuemeka and Iscioglu (2016) studies (see Table 16). As with the data from the CC-TSML, most differences were statistically ($p < .0001$) and practically significant. The exceptions include the TK construct ($p = .008$, $d = .38$) and

Table 16

*Comparison of means and SDs between Koh et al., 2014 and Chukwuemeka & Iscioglu, 2016*

| | Koh et al., 2014 *n* = 354 | | Chukwuemeka & Iscioglu (2016) *n* = 53 | | Independent sample *t*-test | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Scale | *M* | *SD* | *M* | *SD* | *p* (2-tailed) | Δ *M* | *SE* | *t* | *df* | Cohen's *d* |
| TK | 5.17 | 0.98 | 5.56 | 1.05 | .0077 | .39 | .15 | 2.68 | 405 | .38 |
| TPACK | 4.86 | 1.13 | 5.91 | 0.84 | < .0001 | 1.05 | .16 | 6.50 | 405 | 1.05 |
| PK | 5.56 | 0.77 | 6.47 | 0.56 | < .0001 | .91 | .11 | 8.28 | 405 | 1.35 |
| TPK | 5.17 | 0.98 | 5.80 | 0.97 | < .0001 | .63 | .14 | 4.37 | 405 | .65 |
| PCK | 5.43 | 1.05 | 5.57 | 1.28 | .3803 | .14 | .16 | .88 | 405 | .12 |
| CK | 5.84 | 0.93 | 6.55 | 0.69 | < .0001 | .71 | .13 | 5.34 | 405 | .87 |
| TCK | 5.20 | 1.09 | 5.86 | 0.93 | < .0001 | .66 | .16 | 4.18 | 405 | .65 |

*Note*. Cohen's $d = (M_2 - M_1)/\sqrt{((SD_1^2 + SD_2^2)/2)}$. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

the PCK construct (*p* = .3803, *d* = .12). The differences in the TK construct are both statistically and practically significant with a medium effect size (Cohen, 1988) while the differences in the PCK construct are not significant. Other constructs show statistically (*p* < .0001) and practically significant differences (*d* = .65 – 1.35; see Table 16). Differences between Koh et al. (2014) and Chukwuemeka and Iscioglu (2016) data are statistically significant with large effects in the PK, CK, TCK, and TPACK constructs.

Table 13 shows the implied correlations, average variance extracted, and composite reliability of the data from the CFA of the present study. Table 17 shows the observed correlations from the 866 cases used in the CFA for the CC-TSML. Table 24 in the following chapter shows the observed correlations from the CC-TSML in contracts with the correlations from Koh et al. (2013) and Koh et al. (2014). Table 24 is included with the discussion in the following chapter for the reader's ease of use.

Table 17

*Observed factor correlations from the CC-TSML*

| CC–TSML Subscale | TK | TPACK | PK | TPK | PCK | CK | TCK |
|---|---|---|---|---|---|---|---|
| TK | 1.00000 | | | | | | |
| TPACK | .48400 | 1.00000 | | | | | |
| PK | .39300 | .29200 | 1.00000 | | | | |
| TPK | .57800 | .58400 | .47200 | 1.00000 | | | |
| PCK | -.006** | -.012** | .19500 | -.008** | 1.00000 | | |
| CK | .23800 | .16300 | .44500 | .23000 | .16900 | 1.00000 | |
| TCK | .54500 | .50800 | .31400 | .64200 | .033** | .26000 | 1.00000 |

*Note*. *p* < .001 except ***p* = n.s. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

**Hypotheses Outcomes**

CFA Hypotheses H2.1, H2.4, H2.5, and H2.7 were partially supported. Table 18 provides details on the hypotheses and how well they were supported, as well as summary notes for those that were only partially supported. Hypotheses H2.2 and H2.3 were fully supported and hypotheses H2.6 was supported when fit indices were considered in light of sample size and model complexity (Hair et al., 2015).

Table 18

*CFA hypotheses outcomes*

| CFA Hypotheses | | Supported | Notes |
|---|---|---|---|
| H2.1 | Pattern coefficients will be greater than .70 | Partially | TK_1 = .563<br>TK_2 = .596<br>TK_6 = .663<br>TK_7 = .670<br>PK_1 = .641<br>TCK_1 = .631 |
| H2.2 | Structure coefficients will load most heavily on their respective factors | Yes | |
| H2.3 | Composite reliability (CR) for each construct will be greater than .70 | Yes | |
| H2.4 | Convergent validity as measured by pattern coefficients greater than.70 and less than .95 and average variance extracted (AVE) greater than 0.50 | Partially | TK_1 = .563<br>TK_2 = .596<br>TK_6 = .663<br>TK_7 = .670<br>TK AVE = .436<br>PK_1 = .641<br>PK AVE = .631<br>TCK_1 = .631<br>TCK AVE = .543 |
| H2.5 | Discriminant validity as measured by the square root of the AVE will be greater than the individual factor correlations | Partially | TK = .660<br>TK --> TCK = .669<br>TCK = .737<br>TCK --> TPK = .772 |

| CFA Hypotheses | | Supported | Notes |
|---|---|---|---|
| H2.6 | Data from the TPACK will yield good global fit indices as measured by: TLI ≥ .95, CFI ≥ .95, RMSEA ≤ .06, SRMR ≤ .05 | Yes* | Using TLI and CFI thresholds ≥ .90 (Hair et al., 2015) allows the 7-factor correlated model to fit both absolute and comparative fit indices. |
| H2.7 | Data from the TPACK will yield absolute value of residual correlations less than .10 | Partially | 9 absolute value of residual correlations greater than .10 |

## Common Method Variance

Following the procedures from Williams et al. (2010) and a systematic check introduced in Shuck, Nimon, and Zigarmi (2017), a CFA marker technique was used to test for common method variance (CMV). The eight-item Miller and Chiodo (2008) ATTCB marker variable set was included with the CC–TSML and used to test for CMV. The ATTCB latent factor and its items were added to the 7-factor correlated model (measurement model) from the CFA to create the CFA with CMV model. The baseline model, the model used to test CMV method effects, was created by adding the CMV item regression weights and error variances as well adding covariance paths from each latent marker to the CMV latent variable and setting those covariances to zero. The Method-C model, the constrained model, began with the baseline and added a path from all the substantive items to the CMV latent variable and constrained those paths to equality. The Method-U model, the unconstrained model, began with Method-C and removed the constraints on the paths from the substantive items to the CMV marker variable. The Method-R model was used to test for "potential biasing effect of marker variable method

Table 19

*CMV model fit indices*

| Model | $\chi^2$ | *df* | CFI | RMSEA | LO 90 | HI 90 | Compare | $\Delta \chi^2$ | $\Delta$ *df* | *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| CFA | 2721.892 | 644 | .890 | .061 | .059 | .063 | | | | |
| Baseline Prep | 2721.892 | 660 | .891 | .060 | .058 | .062 | | | | |
| Baseline | 2738.768 | 667 | .891 | .060 | .058 | .062 | | | | |
| Method-C | 2733.203 | 666 | .891 | .060 | .058 | .062 | Baseline | 5.565 | 1 | .018 |
| Method-U | 2689.440 | 637 | .892 | .061 | .059 | .063 | Method-C | 43.763 | 29 | .039 |
| Method-R | 2689.566 | 658 | .893 | .060 | .057 | .062 | Method-U | 0.126 | 21 | 1.000 |

variance on factor correlations" (Williams et al., 2010, p. 494). Table 19 shows the CMV model fit indices for the various models.

Comparing the fit indices of the baseline model to the constrained model (Method-C) tested for the "presence of equal method effects associated with the marker latent variable" (Williams et al., 2010, p. 494) while the unconstrained model (Method-U) allowed for different method effects. In the present study, both Method-C and Method-U were statistically significant at the $p < .05$ level. This indicates that there may be some CMV present in the data and it may impact some factors more than others. Method-U was chosen as the comparison model to Method-R due to its fit indices (e.g.., lower $\chi^2$, higher RMSEA and CFI). Method-R is not statistically or practically significant when compared to Method-U indicating that any CMV present in the data is not skewing the relationships among the substantive factors.

## Summary

This chapter provided the results of the statistical tests used to evaluate the data and test the hypotheses. Data were collected in January and February 2018. Data cleaning procedures were used to ensure only high-quality responses were used in the sequential EFA-CFA to test for reliability and validity. Study participants were statistically and practically significantly different from the population of Texas 2-year public college faculty with an overrepresentation of full-time faculty in general and female full-time faculty in particular. The EFA required two items (PK_5 and PK_6) be deleted in order to meet the pattern coefficient threshold for items. No items showed any significant crossloading. All subscales showed internal reliability at the .8 level (Kline, 2016) except TCK (.776) which would have passed the threshold Kline set in the previous edition of his book.

The CFA 7-factor correlated model demonstrated adequate model fit against global and local fit indices. Some local fit issues were seen, particularly with TK items. The TK subscale failed to show discriminant validity with the TCK subscale. Pattern coefficients show several TK items that failed to meet the $\geq .70$ threshold established by Kline (2016). All subscales demonstrated composite reliability. Convergent validity was demonstrated by the CK, PCK, TPK, and TPACK subscales but not the PK, TK, and TCK subscales. Common method variance was tested using the CFA marker technique described in Williams et al., 2010. The data show that CMV is present ($p < .05$) and statistically significant, it is not practically significant and does not impact the relationships among the TPACK variables.

# Chapter 5 – Discussion

This chapter discusses the results of the statistical analyses, implications of the research, and limitations of the present study, as well as suggesting paths of future research. The discussion of the statistical analyses will help convey the significance of the EFA and CFA results in the context of measurement theory and prior research. Implications of the research for TPACK theory development, TPACK survey development, and postsecondary educational institutions are also discussed. Limitations of the present study will be highlighted to assist the reader in understanding under which conditions the study results apply. Suggestions for future research include ways that this researcher and others can build upon the results of this dissertation.

## Study Participants

There are statistically and practically significant differences between the CC-TSML study participants and Texas community college faculty population (THECB, 2017; see Table 7). All differences were statistically significant at the $p < .001$ level with the exception of part-time faculty by gender ($p = .007$). The most significant practical difference based on the Cramer's $V$ was a large effect (.1 = small effect, .3 = medium effect, .5 = large effect; Cohen, 1988) seen in the total faculty by status (e.g., full-time, part-time). When one considers the connectedness of faculty to the institution, in this case shown by attentiveness to the institutional email account, it is logical that more full-time faculty would respond to an email invitation sent to their institutional email address.

Practical significance at the moderate level (Cohen, 1988) is seen for full-time faculty by gender with more females than males responding, a common theme in survey research (e.g., Sax, Gilmartin, Lee, & Hagedorn, 2008). Moderate to small practically significant effects (Cohen, 1988) were seen for total faculty by gender and part-time faculty by ethnicity. Total faculty by ethnicity, part-time faculty by gender, and part-time faculty by ethnicity all showed small effects based on Cohen's (1988) guidelines for interpreting Cramer's *V*. Overall, while all compared faculty characteristics (Table 7) are statistically significant, the only practically significant results are from the overrepresentation of full-time faculty with large effects and the overrepresentation of full-time females with moderate effects (Cohen, 1988).

## Exploratory Factor Analysis

In the EFA, one-third of responses (*n* = 433) were analyzed following recommendations in Bates et al. (2012) and Worthington and Whitaker (2006). The sample demonstrated both sampling adequacy and sufficiently correlated data. During all three EFA iterations, no item violated H1.2.

When evaluating the pattern matrices according to H1.1 after the initial factor analysis, PK_5 ("I am able to plan group activities for my students.") had a pattern coefficient of .427, which is less than the .50 (Costello & Osborne, 2005) threshold in H1.1. This item was eliminated in subsequent iterations. Chai et al. (2013) also removed this item due to low factor loading.

The second iteration revealed that item PK_6 ("I am able to guide my students to engage in effective discussion during group work.") had a pattern coefficient of .497, just below the threshold of .50 (Costello & Osborne, 2005). While other studies (Chai et al., 2013; Koh et al., 2014) had pattern coefficients of .75 or higher for this item, in Texas community college faculty the item itself accounts for less than 25% of the total item variance (Hair et al., 2015) and was dropped from the analysis per H1.1.

In the third iteration, all retained items met the minimum pattern matrix coefficient of .50 and no items exhibited cross-loading of .32 or more per Costello and Osborne (2005) in line with H1.1. The structural coefficients of all items loaded most heavily on their respective factors (Graham, Guthrie, & Thompson, 2003) supporting H1.2. See Table 8 for the full EFA pattern and structure coefficients by item and construct.

After the third iteration, internal reliability coefficients for the subscales were evaluated. Cronbach's alpha for TK = .869, TPACK = .945, PK = .859, TPK = .908, PCK = .928, CK = .814, and TCK = .776. The TCK subscale was the only one that did not meet the Henson (2001) .80 threshold in H1.3, partially supporting H1.3. Koh et al. (2014) reported alphas consistently higher than the ones found in this study (see Table 20) perhaps due to the sample (in-service PK–16 teachers) or context (participants in a professional development program related to technology integration).

Table 20

*Internal reliability estimates comparison with Koh et al., 2014*

| Cronbach's Alpha | TK | TPACK | PK | TPK | PCK | CK | TCK |
|---|---|---|---|---|---|---|---|
| Koh et al., 2014 | .94 | .96 | .94 | .95 | .93 | .95 | .92 |
| CC–TSML* | .87 | .95 | .86 | .91 | .93 | .81 | .78 |
| Difference | .07 | .02 | .08 | .04 | .00 | .14 | .14 |

*Note.* *= data from the CC-TSML is reported to 2 decimal places here to compare with Koh et al., 2014, which only uses 2 decimal places. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

## Confirmatory Factor Analysis

The subscales for the CC–TSML were evaluated using the 866 cases left after the EFA analyses. The CFA hypotheses tested for pattern and structure coefficients, composite reliability, convergent validity, discriminant validity, global fit indices, and absolute value of residual correlations, a local fit index. Taken together, these statistical tests provide researchers with information on how well the observed data fit the hypothesized model based on theory. Because the data demonstrated non-normality, bootstrapping was used and the data were compared. The bootstrapped data did not produce statistically significantly different results from the non-bootstrapped data (cf. Byrne, 2010; Kline, 2016). Both Byrne (2010) and Kline (2016) suggest that non-normal data may be expected in some cases.

### Model Fit and Absolute Value of Residual Correlations

Hypotheses H2.6 and H2.7 address global and local fit indices. In H2.6, data from the CC–TSML were compared to absolute fit indices RMSEA (≤ .06) and SRMR (≤ .05) and comparative fit indices TLI and CFI, both greater than or equal to .95 (cf. Schumacker & Lomax, 2016). In H2.7, the data from the CC–TSML were evaluated for local fit using absolute value of residual correlations less than .10 (cf. Kline, 2016). Table 11 shows the fit indices for 7-factor correlated model ($\chi^2 = 1352.52$, $df = 384$, $p < .001$). Model fit for the absolute fit indices RMSEA and SRMR are met with the thresholds suggested by Schumacker and Lomax (2016). The TLI and CFI fit statistic was below the .95 threshold suggested by Schumacker and Lomax. Using TLI and CFI fit statistics based on simulation studies, Hair et al. (2015) suggest that a TLI and CFI greater than or equal to .90 is sufficient for samples larger than 250 with more than 30 items. When considered in this light, the 7-factor correlated model demonstrates adequate model fit, meaning that using these global fit indices, the data fit the theoretical model well.

Absolute value of residual correlations provide information on local fit (Kline, 2016). Nine pairs of items produced absolute correlations greater than .10. Inspecting the nine pairs for some type of pattern, as recommended by Kline (2016), highlighted the involvement of a number of TK items (TK_2, TK_3, TK_4, TK_6, and TK_7), most of which also have demonstrated low pattern coefficients. These may indicate a need to refine the model (e.g., Byrne, 2010; Kline 2016). Attempts at refining the model based on the absolute correlation residual pairs and modification indices from the 7-factor correlated mode were made by correlating error terms for several TK items. These attempts did not yield statistically and practically significant better model fit. Given these items have already been identified as problematic in the CC–TSML sample, correlating the error terms in an effort to seek better global model fit was not justifiable. Adequate model fit was achieved with 7-factor correlated model, the model expected and justified in literature (e.g., Mishra & Koehler, 2006; Koh et al., 2014).

## Reliability and Validity

Hypotheses H2.1 and H2.2 tested the subscale items for their relationship to the factors. Pattern coefficients provide a measure for item correlation with its factor with the squared pattern coefficient, revealing how much of the item's total variance is accounted for by the factor (Hair et al., 2015). Structure coefficients provide "simple correlations between variables and factors, but these loadings contain both the unique variance between variables and factors and the correlation among factors" (Hair et al., 2015, p. 117).

The CC–TSML subscales generally support H2.1 with some notable exceptions. In the TK subscale, items TK_1 = .56, TK_2 = .60, TK_6 = .66, and TK_7 = .67 fail to meet the pattern coefficient threshold (> .70; cf. Hair et al., 2015). In the PK subscale, item PK_1 = .64, and in the TCK subscale, item TCK_1 = .63, fail to meet the H2.1 threshold. All items provide structure coefficients that load most heavily on their expected factors (H2.2). The low pattern coefficients indicate that the amount of unique variance accounted for by each item is less than the error variance associated with the item. The items are practically and statistically significant (cf. Hair et al., 2015), but they appear to be weak indicators in this sample. Comparing these pattern coefficients to those in the Koh et al. (2014) study provides additional information (see Table 21).

In the TK subscale, data from the CC–TSML had lower pattern coefficients for every item in the subscale; furthermore, the composite reliability of the subscale is .07 lower than that found from Koh et al. (2014) data. The TK subscale is designed to measure knowledge about current technologies (Cox & Graham, 2009; Misha & Koehler, 2006; Graham, 2011). The items were published in 2014 (Koh et al., 2014) and were vetted by an expert committee of Texas community college and university faculty in 2017; however, these items do not seem to have adequately captured the technological knowledge of Texas community college faculty. When other TK-related construct items (TCK, TPK, and TPACK) are inspected, only item TCK_1 (.631) has a pattern coefficient below the study threshold. The TCK_1 item may be problematic for Texas community college faculty because many of them may not perceive having software programs that are specifically created for their teaching subject. For example, English professors may not view word processing software as “specifically created” for their

Table 21

*Pattern coefficient and composite reliability comparison between Koh et al. (2014) and CC–TSML*

| CC–TSML Subscale | Item (wording from CC–TSML) | Koh et al.(2014) | CC–TSML | Δ |
|---|---|---|---|---|
| *TK* | | | | |
| TK_1 | I am able to create web pages. | .66 | .56 | .10 |
| TK_2 | I am able to use social media. | .72 | .60 | .12 |
| TK_3 | I am able to use online collaboration tools. | .84 | .83 | .01 |
| TK_4 | I am able to use online communication tools. | .83 | .73 | .10 |
| TK_5 | I am able to use online note-taking tools. | .87 | .76 | .11 |
| TK_6 | I am able to use online mind-mapping tools. | .86 | .66 | .20 |
| TK_7 | I am able to use online visualization tools (e.g., Wordle, Quizlet). | .80 | .67 | .13 |
| | *Composite Reliability* | .93 | .86 | .07 |
| *TPACK* | | | | |
| TPACK_1 | I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools. | .65 | .82 | .17 |
| TPACK_2 | I can design authentic problems about the content knowledge and represent them through digital technology to engage my students. | .73 | .87 | .14 |
| TPACK_3 | I can structure activities to help student construct different representations of content knowledge using appropriate digital technology tools. | .73 | .89 | .16 |
| TPACK_4 | I can create self-directed learning activities of the content knowledge with appropriate digital technology tools. | .73 | .90 | .17 |
| TPACK_5 | I can design inquiry-based activities to guide students to make sense of the content knowledge with appropriate digital technology tools (e.g., simulations, web-based materials). | .75 | .83 | .08 |
| | *Composite Reliability* | .84 | .94 | .10 |
| *PK* | | | | |
| PK_1 | I am able to stretch my students' thinking by creating challenging tasks for them. | .77 | .64 | .13 |
| PK_2 | I am able to guide my students to adopt appropriate learning strategies. | .80 | .83 | .03 |
| PK_3 | I am able to help my students to monitor their own learning. | .80 | .83 | .03 |

| CC–TSML Subscale | Item (wording from CC–TSML) | Koh et al.(2014) | CC–TSML | Δ |
|---|---|---|---|---|
| PK_4 | I am able to help my students to reflect on their learning strategies. | .83 | .85 | .02 |
| PK_5 | I am able to plan group activities for my students. | .82 | N/A | |
| PK_6 | I am able to guide my students to engage in effective discussion during group work. | .82 | N/A | |
| | *Composite Reliability* | .92 | .74 | .18 |
| *TPK* | | | | |
| TPK_1 | I am able to use technology to introduce my students to real world scenarios. | .64 | .73 | .09 |
| TPK_2 | I am able to facilitate my students' use of technology to find more information on their own. | .68 | .79 | .11 |
| TPK_3 | I am able to facilitate my students' use of technology to plan and monitor their own learning. | .74 | .81 | .07 |
| TPK_4 | I am able to facilitate my students' use of technology to construct different forms of knowledge representation. | .70 | .84 | .14 |
| TPK_5 | I am able to facilitate my students' collaboration to collaborate with each other using technology. | .63 | .74 | .11 |
| | *Composite Reliability* | .81 | .89 | .08 |
| *PCK* | | | | |
| PCK_1 | Without using technology, I can address the common misconceptions my students have about my teaching subject. | .89 | .81 | .08 |
| PCK_2 | Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my teaching subject. | .93 | .92 | .01 |
| PCK_3 | Without using technology, I can help my students to understand the content knowledge of my teaching subject through various ways. | .91 | .88 | .03 |
| | *Composite Reliability* | .94 | .90 | .04 |
| *CK* | | | | |
| CK_1 | I have sufficient knowledge about my teaching subject. | .77 | .71 | .06 |
| CK_2 | I can think about the content of my teaching subject like a subject matter expert. | .84 | .89 | .05 |
| CK_3 | I am able to develop a deeper understanding about the content of my teaching subject. | .80 | .78 | .02 |

| CC–TSML Subscale | Item (wording from CC–TSML) | Koh et al.(2014) | CC–TSML | Δ |
|---|---|---|---|---|
| | *Composite Reliability* | .85 | .84 | .01 |
| *TCK* | | | | |
| TCK_1 | I can use the software programs that are created specifically for my teaching subject. | .74 | .63 | .11 |
| TCK_2 | I know about the technologies that are available for me to use for the research of content of teaching subject. | .65 | .76 | .11 |
| TCK_3 | I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my teaching subject. | .61 | .81 | .20 |
| | *Composite Reliability* | .71 | .78 | .07 |

*Note*. *= data from the CC-TSML is reported to 2 decimal places here to compare with Koh et al., 2014, which only uses 2 decimal places. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

subject even though word processing is commonly used in English instruction. This item may be even more problematic for faculty who teach in other disciplines.

For item PK_1, the data from the CC–TSML produced a much lower pattern coefficient for this item than any of the other items in the subscale. It also has the lowest pattern coefficient in the subscale in the Koh et al. (2014) study. In Chai et al. (2013), the item was removed due to low factor loading; however, the authors do not offer a reason why they believe this item may not have performed well in their study. It is impossible to adequately compare this subscale across the Koh et al. (2014) and CC–TSML studies, because PK_5 and PK_6 were dropped from the CFA analysis in this study due to low factor loading. The composite reliability for this subscale is .18 below that found from the Koh et al. (2015) data.

Hypotheses H2.3, H2.4, and H2.5 evaluate the CC–TSML subscale data on composite reliability, convergent validity, and discriminant validity. Composite reliability is a measure of internal reliability of the construct or subscale and is calculated by using pattern coefficients and the error variance, providing a ratio of the variance explained by the construct over the total variance (Kline, 2016). According to Hair et al. (2015), convergent validity conveys how well the items associated with a construct, as represented by the subscale, “converge or share a high proportion of variance in common” (p. 601), signifying how closely associated the items within a construct are to each other. Discriminant validity is the “extent to which a construct is truly distinct from other constructs both in terms of how much it correlates with other constructs and how distinctly measured variables represent only this single construct” (Hair et al., 2015, p. 601). Discriminant validity tells us whether the construct, as measured by the subscale, is distinct from other constructs by examining its correlations with the other constructs and the items to determine whether they measure only the construct they are purported to measure.  A summary chart of how each CC–TSML subscale performed on composite reliability, convergent reliability, and discriminant validity is shown in Table 22.

As Table 22 shows, all subscales demonstrated composite reliability using the .70 threshold from Hair et al. (2015). The higher the composite reliability, the greater amount of the variance is explained by the construct, signifying that TPACK explains the most variance (TPACK = .930), followed by PCK = .904, TPK = .887, TK = .860, CK = .838, TCK = .779; and PK = .741. The data from Koh et al. (2014) showed composite reliability of PCK = .94, TK = .93, PK = .92, CK = .85, TPACK = .84, TPK = .81, and TCK = .71 (see Table 21).

Comparing the composite reliabilities in Table 21, the data from the CK construct are very similar in both samples, indicating these items work well in both the Koh et al. (2014) and CC–TSML (see Table 21). When considering all the CK-related constructs (CK, PCK, TCK, and TPACK), all have differences of .10 or less, suggesting that the CK-related items overall capture the constructs well in both the Singaporean PK–16 and the Texas community college samples.

Table 22

*Composite reliability, convergent validity, and discriminant validity for CC–TSML subscales*

| CC–TSML Subscale | Composite Reliability | Convergent Validity | Discriminant Validity |
|---|---|---|---|
| CK | Yes | Yes | Yes |
| PK | Yes | Partial | Yes |
| TK | Yes | No | No |
| PCK | Yes | Yes | Yes |
| TCK | Yes | Partial | No |
| TPK | Yes | Yes | Yes |
| TPACK | Yes | Yes | Yes |

*Note*. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

The CC–TSML data show a consistently higher composite reliability for TK-related constructs (TPACK, TPK, TCK) with the exception of a lower TK composite reliability. Table 21 shows that the TK-related constructs (TK, TCK, TPK, and TPACK) have composite reliability differences of .10 or less, indicating that overall the items capture the constructs adequately in both the Koh et al. (2014) and CC–TSML samples. This does not negate the prior noted issues with the TK items themselves even though the subscale performs adequately. Rather it is additional evidence that the TK subscale items do not resonate as well with Texas community college faculty as they do with the Koh et al. (2014) sample.

The PK subscale shows a large difference (.18), which may be related to the deletion of items PK_5 and PK_6 in the EFA in the CC–TSML data as well as the low factor loading for item PK_1 (see Table 21). The PK subscale items are based on learner-centered principles (Chai et al., 2011). The CC–TSML sample self-reports that (a) 61.3% have six or more college credits in teaching methods or pedagogy, (b) 71.1% have not been certified to teach at the high school level in the last 15 years, and (c) 61.1% of them are aged 50 or older. It may be possible that we are seeing the results of faculty who have been formally trained in teaching methods and pedagogical practices prior to the focus on learner-centered principles, concepts that were not fully developed by the APA until 1997.

As stated in H.2.4, convergent validity will be measured by pattern coefficients greater than .70 (Kline, 2016) and less than .95 (cf. Bagozzi & Yi, 1988) and AVE greater than .50 (cf. Bagozzi & Yi, 1988). Table 23 shows the AVE of the seven TPACK subscales included in the Koh et al. (2014) and the present study of the CC–TSML. Items TK_1, TK_2, TK_6, TK_7, PK_1, and TCK_1 with pattern coefficients less than .70 have already been noted. No items had a pattern coefficient greater than .95. When reviewing the AVE, data from the CK and PK subscales demonstrate about the same ability to extract variance in both the Singaporean PK–16 and Texas community college faculty groups. The data from the Koh et al. (2014) sample show a higher AVE in the PCK subscale than is shown in the Texas community college data, whereas in the TCK subscale the opposite is true. Furthermore, excluding the TK subscale where issues have already been noted, the rest of the TK-related constructs have considerably higher AVE in Texas community college faculty than in the Singaporean PK–16 faculty. This suggests that learner-centered pedagogy, in which Singaporean faculty are formally trained, may be influencing the data in the PCK subscale. This may also account for the negative and insignificant implied factor loadings associated with PCK in the CC–TSML data. The AVE of the TK-related constructs of TCK, TPK, and TPACK may be indicative of efforts at the community college level to increase online course offerings (Levin, Kater, & Wagoner, 2006; THECB, 2015; Wyner, 2014).

Table 23

*AVE comparison between Koh et al., 2014 and CC–TSML*

| CC–TSML Subscale | Koh et al., 2014 | CC–TSML | Δ |
|---|---|---|---|
| CK | .65 | .64 | .01 |
| PK | .65 | .63 | .02 |
| PCK | .83 | .76 | .07 |
| TCK | .45 | .54 | .09 |
| TPK | .46 | .61 | .15 |
| TK | .64 | .44 | .20 |
| TPACK | .52 | .75 | .23 |

*Note*. CC-TSML = Community College TPACK Survey for Meaningful Learning. TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

## Means, Standard Deviations, and Observed Correlations

When data does not display multivariate normality, bootstrapping can be used to test whether or not statistically significant differences occur when using bootstrapped versus non-bootstrapped data as suggest by Kline (2016) and Byrne (2010). Another consideration is what could be considered normal for the sample (Byrne, 2010; Kline, 2016). For example, when comparing the means and standard deviations of the construct scale scores from the CFA of the present CC-TSML study to the data from the Koh et al. (2014) study using unpaired *t*-tests, Texas community college have a higher mean for every construct except technology (see Table 14). When compared to PK–16 teachers from Singapore engaged in professional development programs related to technology integration in the classroom (Koh et al. 2014), Texas community college faculty rate themselves higher in content knowledge ($p < .0001$, $t = 15.02$, $df = 1218$, $d = .86$). This is a statistically significant and large effect. Given that most Texas community college faculty hold Master's degrees in their teaching areas (SACSCOC, 2006), it is logical that they would rate themselves highly in this area. When comparing Texas community college faculty who participated in the CC-TSML to university faculty teaching in the College of Education in Cyprus (Chukwuemeka & Iscioglu, 2016), the difference is statistically and practically insignificant in the content knowledge construct. Reviewing Table 16 shows that Cypriot university faculty have a statistically and practically significant difference in CK when compared to the Koh et al. (2014) sample. From this information, one could surmise that high CK scores are normal for college and university faculty.

Table 15 shows that Cypriot university faculty in a College of Education have statistically ($p < .001$) and practically significant differences with Texas public 2-year college faculty in the CC-TSML sample in the PK construct. If one considers the context of both studies, it is a logical difference. College of Education university faculty who are participating in a research project using the TPACK theory (Mishra & Koehler, 2006) have undoubtedly been exposed to at least some theories of teaching competencies, learner-centered principles, and technology-enriched teaching and learning. The CC-TSML participants have no such context. Not only is the present research not ensconced in a professional development program (e.g., Koh et al., 2014), only some of the faculty participating in the CC-TSML have had formal pedagogical training in learner-centered strategies or technology-enhanced lessons. Interestingly, Texas 2-year public college faculty who participated in the CC-TSML also have a statistically and practically significant ($p < .001$, $d = .46$) difference with a moderate effect size to the PK-16 faculty in the Koh et al. (2014) sample (see Table 14). Even without the context, Texas community college faculty feel quite sure about their PK but not as certain as their Cypriot colleagues.

The means and standard deviations between Chukwuemeka and Iscioglu (2016; see Table 15), show insignificant differences in the TPK, CK, and TCK constructs. This means that while the difference between Koh et al. (2014) and the present study (see Table 14) and the difference between Koh et al. (2014) and Chukwuemeka and Iscioglu (2016; see Table 16) are statistically significant ($p < .001$) for these constructs, the higher education faculty show no statistical or practical significance.

## Observed Correlations

Observed correlations for the CC-TMSL, Koh et al., 2013, and Koh et al., 2014 are shown in Table 24. The observed factor correlations show positive and significant factor correlations for all constructs except PCK to TK (-.01, $p = .851$), PCK to TPACK (-.01, $p = .735$), PCK to TPK (-.01, $p = .812$), and PCK to TCK (.03, $p = .332$). The PCK constructs show primarily negative but insignificant observed correlations with the TK-related constructs, contrary to what is found in the other research using closely related versions of this instrument (e.g., Koh et al., 2013; Koh et al., 2014). Koh et al. (2014) found statistically significant (*p* < .001) correlations among all its factors with the exception of PCK to TK (.12, *p* < .05), its weakest correlation. Koh et al. (2013) showed statistically significant correlations (*p* < .001) among all seven TPACK factors. Koh et al. (2013) showed lower correlations with PCK to TK-related constructs (.15–.23) in contrast to much higher correlations among other factors (e.g., TPK to TPACK = .74). Similarly, Koh et al. (2014) showed lower correlations between PCK to TK-related constructs (.12 - .27) than it did between other factors (e.g., TPK to TPACK = .80). When reviewing the CC–TSML data, we find a similar pattern with correlations between PCK the TK-related constructs showing insignificant correlations, whereas other factor correlations are statistically significant and much higher (e.g., TPK to TPACK = .627).

Table 24

*Observed factor correlations from Koh et al., 2013; Koh et al., 2014; and CC-TSML*

| CC–TSML Subscale | TK | TPACK | PK | TPK | PCK | CK | TCK |
|---|---|---|---|---|---|---|---|
| TK | 1.0000 | .69, .74 | .42, .37 | .72, .69 | .18, .12* | .35, .33 | .63, .68 |
| TPACK | .4800 | 1.0000 | .55, .50 | .74, .80 | .23, .14 | .44, .29 | .72, .71 |
| PK | .3900 | .2900 | 1.0000 | .49, .62 | .40, .31 | .61, .64 | .39, .51 |
| TPK | .5800 | .5800 | .4700 | 1.0000 | .15, .15 | .34, .36 | .65, .67 |
| PCK | -.01** | -.01** | .2000 | -.01** | 1.0000 | .42, .45 | .20, .27 |
| CK | .2400 | .1600 | .4500 | .2300 | .1700 | 1.0000 | .47, .53 |
| TCK | .5500 | .5100 | .3100 | .6400 | .03** | .2600 | 1.0000 |

*Note.* Lower diagonal contains correlations from the present study; upper diagonals contain correlation from Koh et al. (2013), Koh et al. (2014). ***p* = n.s. **p* < .05
TK = technological knowledge. TPACK = technological pedagogical content knowledge. PK = pedagogical knowledge. TPK = technological pedagogical knowledge. PCK = pedagogical content knowledge. CK = content knowledge. TCK = technological content knowledge.

## Common Method Variance

The CFA marker technique from Williams et al. (2010) with a new procedural check model (Baseline Prep) from Shuck et al. (2017) was used to test for CMV in the CC-TSML data.  Table 19 shows the CMV model fit indices for the various models. Both the constrained model (Method-C) and unconstrained model (Method-U) showed statistically significant differences ($p < .05$) with Method-U indicating better model fit. This indicates that there may be CMV present (Method-C) and that it may not be equal among substantive items (Method-U).  However, when the Method-R (restricted model) was compared to Method-U.  Method-R showed no statistical ($p = 1.000$) or practical significance.  This indicates that while there may be some statistically significant ($p < .05$) CMV present in the data and it may not be equal among all substantive items, it is not practically significant and is not impacting the relationships among the substantive variables.

## Implications

The present study has implications for TPACK theory, TPACK survey development, and postsecondary educational institutions. TPACK theory was developed using a wide variety of faculty (Mishra & Koehler, 2006), yet there is very little research using TPACK theory with postsecondary faculty samples, particularly in the United States. While U.S. TPACK survey development began in earnest in 2009 (e.g., Schmidt et al., 2009), almost all recent work has been done abroad, rarely focusing on postsecondary faculty in any country. As such, the present research provides one of the only windows into TPACK development as measured by a survey instrument in a large U.S. postsecondary sample. Because the present study is based on the *60x30TX* strategic plan for higher education in Texas, it also has direct implications for Texas community colleges and their faculty.

## Implications for TPACK Theory

TPACK theory was initially developed by Mishra and Koehler (2006) after five years of studies involving faculty from elementary, secondary, and postsecondary institutions. TPACK theoretical development (cf. Cox & Graham, 2009; Graham, 2011) has improved understandings of boundary constructs. Most research on TPACK is being conducted using preservice and in-service PK–12 faculty. In order to achieve and maintain certifications in the United States, teachers are formally trained in both learner-centered teaching methods and technology integration, unlike their postsecondary counterparts. While TPACK theory was developed using postsecondary faculty, the research community has largely ignored them since. Faculty in community colleges encounter at-risk students daily in their physical and virtual classrooms. In order to help these students achieve success, it is important to use best practices in teaching methods and technology integration. Using postsecondary faculty as research participants is the only way to gauge faculty knowledge base as well as where updated and upgraded skill sets are required to meet the changing needs of students.

In the present research, it was discovered that the CC–TSML as currently constituted has discriminant validity issues between the TK, TCK, and TPK constructs. These are the same issues that Cox and Graham (2009) identified nine years ago. Because postsecondary faculty have not been consistently used as samples in TPACK research, it is unclear if the boundary constructs are truly at issue or if the items should be somewhat different to generate appropriate data in a population sample lacking formal training in current pedagogy and technology integration.

It is considerably harder to conduct research with postsecondary faculty than PK–12 faculty. The reporting standards for demographics are varied from one state to the next and may or may not conform with data being reported to the federal government via IPEDS (e.g., Texas ethnicity categories are not the same as federal ethnicity categories). For example, it is impossible to compare the sample in this research to the population of Texas community college faculty based on age as neither Texas nor IPEDS collects data on faculty age—a standard demographic in research populations. Postsecondary faculty are difficult to study—there are fewer of them, they are more geographically diverse, they tend to focus on their own disciplines, and they have low response rates; however, it is incumbent upon the research community to design and develop research protocols that focus on postsecondary faculty in order to help make them aware of the knowledge, skills, and abilities they need to be successful in the classroom. Their classroom success is important for the success of their students.

### Implications for TPACK Research

Only four studies have been identified that attempt to test TPACK theory in postsecondary faculty, none of which use U.S. faculty in their samples (Chukwuemeka & Iscioglu, 2016; Jang & Chang, 2016; Rienties et al., 2013; Rienties et al., 2014). Studies by Rienties et al. in 2013 and 2014 were conducted with small ($n < 75$) samples of Dutch faculty that included a few faculty from a variety of other European countries as well as one participant from the United States (Rienties et al., 2013). Rienties et al. used a purpose-built survey designed to measure course “design and usage of technology-enhanced learning in the academics' practice" (p. 14) instead of self-reports of ability or knowledge (Rienties et al., 2013, 2014). Their studies were concerned with professional development programs and improving teaching practice rather than simply measuring TPACK (Rienties et al., 2013, 2014). Because they did not measure TPACK using the usual seven constructs, their results cannot be evaluated against the results in the CC–TSML study. The instrument used in Jang and Chang (2016) did not extract the seven factors of TPACK and also cannot be used to compare data.

Only the Chukwuemeka and Iscioglu (2016) study conducted with 53 Cypriot university faculty using the Koh et al. (2013) instrument and reporting construct means can be used to compare postsecondary faculty to postsecondary faculty. The sample of faculty is similar to the CC–TSML sample in that more female (52.8%) and full-time faculty (71.7%) faculty participated (Chukwuemeka & Iscioglu, 2016). Differences between the Chukwuemeka and Iscioglu (2016) and CC–TSML samples include small size (*n* = 53) and participants from departments associated with teacher education (e.g., Computer Education and Instructional Technologies Department, Educational Sciences Department). Chukwuemeka and Iscioglu (2016) report construct means of TK = 5.56, CK = 6.55, PK = 6.47, PCK = 5.57, TCK = 5.86, TPK = 5.80, and TPACK = 5.91. Given that the Cypriot faculty all come from departments actively engaged in the process of training new teachers, it is not surprising that their means across constructs would be higher as they have been formally trained in current learner-centered pedagogies and technology in support of education. More detail on the unpaired t-test results between this study and Chukwuemeka and Iscioglu (2016) are available in Table 15.

Only a small number of dissertations have studied TPACK in postsecondary faculty in the United States (Garrett, 2014; Hamilton, 2013; Knolton, 2014; Lavadia, 2017); however, none of them used an instrument appropriate for the task, all but one had insufficient participant-to-item ratios, and none was subsequently published in peer-reviewed journals (see Chapter 2 for critique of these studies). This has left an enormous gap in our understanding of TPACK as it applies to U.S. postsecondary faculty.

This study was designed to help fill that gap in the literature by seeking an instrument that could collect reliable and valid data when used with Texas community college faculty (i.e., CC–TSML). Unpaired t-tests means and standard deviations comparisons Koh et al., 2014 (see Table 14 and Table 16) and Chukwuemeka and Iscioglu, 2016 (see Table 15 and Table 16) demonstrate that Texas community college faculty fall between the sample of PK–16 Singaporean faculty and the Cypriot educational departments' faculty. Given that the CC–TSML sample in the current study represents faculty on the 13-14 level (when compared to PK–16) and from a variety of departments, this is precisely where the Texas community college faculty means should fall.

When comparing the observed factor correlations across Koh et al. (2013, 2014; see Table 24) and the present study, similar patterns of high and low correlations were found, despite the negative and insignificant implied factor correlations of PCK to TK-related constructs. Results indicate that the pattern of high and low correlations is meaningful given that the samples in Koh et al. (2013) and (2014) are faculty who have been formally trained in learner-centered pedagogy and have been participating in teacher education agency professional development programs centered on technology integration.

When testing the EFA and CFA hypotheses, the CC–TSML does show some problems with some PK items and the TK subscale. PK items are learner centered; there is no direct evidence that participants in the present study have any formal knowledge or training in learner-centered principles or pedagogy, which may explain some of the issues with items in that subscale. Most of the TK subscale items show low pattern coefficient loadings causing problems with convergent and discriminant validity with the TCK subscale. These same items later generated local fit issues when absolute value of residual correlations were inspected.

All subscales of the CC–TSML established composite reliability. The subscales for CK, PCK, TPK, and TPACK demonstrate convergent validity. Subscales for PK and TCK exhibit partial convergent validity. The TK subscale fails the convergent validity test using the Kline (2016) threshold; however, had we used Kline (2011) and the .6 threshold, this subscale would have met the test.  TPACK factors for CK, PK, PCK, and TPACK provide discriminant validity; however, TK, TCK, and TPK subscales demonstrate problems with discriminant validity. Overall, CC–TSML demonstrated adequate model fit.

In sum, the CC–TSML provides the first TPACK survey data in a large sample of U.S. postsecondary faculty. It has demonstrated reliability but uncovered some convergent and discriminant validity issues within the Texas community college sample. Overall, the data fit the model but improvements are needed, particularly in the TK subscale.

## Implications for Faculty Development

The present study was prompted by the Texas Higher Education Strategic Plan, *60x30TX*, which focuses on an increased number of Texans achieving certificates or degrees at the postsecondary level by 2030. The opening words of this dissertation are a call to action from the THECB (2015, p. v): "Without bold action, Texas faces a future of diminished incomes, opportunities, and resources." In order to meet the goals of the *60x30TX* plan, community colleges and universities will need to implement learner-centered principles and creatively use technology. This study focuses on the community college, the most common place at-risk students will go for educational opportunities, and the KSAs necessary for faculty to help those students achieve success.

In the introduction to this dissertation, the educational process was likened to a manufacturing process to help non-educators and educators alike see similarities to the business problems faced daily by U.S. small and large businesses (see Figure 1; Wyner, 2014). While community colleges have no control over their inputs (students) as open-access educational institutions (Friedel et al., 2014; TEC §130) and they have a larger share of inputs with problems (e.g., academically underprepared students; Bailey et al., 2015; CCCSE, 2016; Mellow et al., 2011; Salinas & Garr, 2009; USDoE, 2010a, 2010b, 2010c, 2010d), they do have control over the processes used by their employees to create the desired outputs of graduates. In order to ensure that community college faculty have the knowledge, skills, and abilities necessary to create the desired outcomes (graduates), Texas community colleges need a simple and effective self-report tool to evaluate professional development programs needed by their faculty, overall and individually.

## Implications for Postsecondary Institutions

For most Texas community colleges, the student-outcomes goals presented in *60x30TX* will require some level of academic organizational change to implement learner-centered principles and technology-rich modalities (Levin et al., 2006; THECB, 2015; Wyner, 2014). Planned change using a theoretical model and faculty involvement is most likely to help the institution get the maximum benefit from the suggested *60x30TX* strategies with the least organizational resistance (Cummings & Worley, 2015; Gilley & Gilley, 2003; Gilley, Godek, & Gilley, 2009; Nevarez & Wood, 2010).

The action research model (Cummings & Worley, 2015) is one that is familiar to many professional educators and may be a good model to start with for Texas community colleges where there may be change fatigue compounded by minimal long-term results (Cummings & Worley, 2015; Gilley & Gilley, 2003; Gilley et al., 2009). The action research model features problem identification, data gathering, joint diagnosis, and action planning, which may be attractive to faculty as talented employees who participate in academic problem diagnosis and action plan development in addressing problems (Cummings & Worley, 2015; Levin et al., 2006; Nevarez & Wood, 2010). This model fits well with the traditional shared governance style of leadership in higher education institutions (e.g., Friedel et al., 2014).

The data from the current CC–TSML and from improved versions of the instrument can serve as a data gathering tool to identify organization-wide, departmental, and individual gaps in KSAs that faculty need in order to provide high-quality teaching across modalities and disciplines (Levin et al., 2006; Mishra & Koehler, 2006; Wyner, 2014). Data gathering with the CC–TSML will allow for customized interventions at any given institution at any level (Cummings & Worley, 2015). The CC–TSML will provide information on faculty professional development and training needs at each institution, based on self-assessments, thereby keeping faculty at the forefront of governance and change initiatives (Burke, 2011; Gilley et al., 2009; Levin et al., 2006; Nevarez & Wood, 2010).

In conjunction with professional development and training programs to support desired faculty KSAs (THECB, 2015; Wyner, 2014), organizational leadership should implement structural changes, strategic human resource management, performance management, and talent management strategies to reinforce desired KSAs (Cummings & Worley, 2015; Gilley et al., 1999; Gilley & Gilley, 2003; Gilley et al., 2009; Nevarez & Wood, 2010). Developing a performance management system that rewards desirable behavior is one means of accomplishing this goal (Cummings & Worley, 2015; Gilley et al., 1999; Gilley & Gilley, 2003). In addition to professional development programs customized to individual faculty and departmental needs based on self-reported needs via the CC–TSML, faculty should have coaches and mentors who can help them become more comfortable with a variety of learner-centered teaching approaches and technology-enrichment plans for their curricula (Burke, 2011; Cummings & Worley, 2015; Wyner, 2014).

Implementing additional strategic human resource management strategies and performance management policies will help ensure that change initiatives improve student outcomes and lead to long-term institutional stability (Gilley et al., 1999; Gilley & Gilley, 2003; Wyner, 2014). Structural approaches to organizational change that support strategic human resource management such as revising faculty job descriptions to explicitly defining needed KSAs beyond content knowledge can help ensure that future hires meet the needs of the institution (Cummings & Worley, 2015; Gilley & Gilley, 2003). Strategic human resource management policies such as relating titles (e.g., professor, assistant professor), promotions (e.g., department chair), raises, and bonuses to evidence-based performance can help ensure that changes in the organization, teaching processes, and student outcomes become deeply embedded in the organization (Burke, 2011; Cumming & Worley, 2015; Gilley et al., 1999; Gilley & Gilley, 2003).

## Limitations

Limitations of this study include lack of age demographics, overrepresentation of full-time female faculty, lack of theoretical context for participants, PK items focused on learner-centered principles, and TK items that failed to resonate with Texas community college faculty. Currently, neither the federal government nor the State of Texas collect age demographics for postsecondary faculty. The lack of this demographic variable makes it impossible to tell whether the high response rate for those 50 years and older is representative of the population or a skewed sample in this study. The response rate was heavily biased in favor of full-time faculty and for females. While similar to the participant sample from the Chukwuemeka and Iscioglu (2016) study, most Texas community college faculty are part time and male. This skew in gender and employment status may have biased the study results. Chukwuemeka and Iscioglu (2016) also found statistically significant differences in male and females when looking at means for TK and PCK with males rating themselves higher in both constructs. Moreover, Chukwuemeka and Iscioglu (2016) also found statistically different means for TK and

TPK for full-time and part-time faculty, with part-time faculty rating themselves higher in these areas.

This study was conducted alone and outside of any professional development context unlike studies using recent versions of the instrument, such as the Chai et al. (2013), Koh et al. (2013), or Koh et al. (2014) studies. Studies using versions of this instrument (e.g., Chai et al., 2013; Koh et al., 2013; Koh et al., 2014; see Table 4) used preservice teacher and in-service teachers in Asian countries with national teacher education programs. In Chai et al. (2013), the sample consisted of 550 preservice teachers in China, Hong Kong, Singapore, and Taiwan, all of whom were attending “highly reputable institutes within their respective locality” (Chai et al., 2013, p. 44). In Koh et al. (2013), the sample data came from 455 in-service teachers in Singapore from PK–16 schools who were participating in research projects associated with a teacher’s college in Singapore and who had participated in a teacher education agency professional development program focused on technology. Koh et al. (2014) received their study data from 354 in-service Singaporean teachers who were also participating in a teacher education agency–sponsored professional development program focused on technology. Each of these teachers had been nominated to serve as technology integration mentors, focusing on those teachers already considered “strong” (Koh et al., 2014, p. 188) in content knowledge and pedagogical knowledge.

Each of these studies (Chai et al., 2013; Koh et al., 2013; Koh et al., 2014) uses a population and sample who have undergone formal teacher education that includes both pedagogy (Chai et al., 2013; Koh et al., 2013; Koh et al., 2014) and technology integration training (Koh et al., 2013; Koh et al., 2014). In contrast, the CC–TSML was conducted with a population and sample who have no formal training requirements in pedagogy or technology integration (SACSCOC, 2006; TEC §130) nor was the study conducted in conjunction with any workshops or training.

While most of the current study's participants report they have six or more college credits in teaching methods or pedagogy (61.03%; see Table 8), very few have been certified to teach high school in the last 15 years (71.1%; see Table 8). Most (55.0%) have never had any formal college courses in technology integration or educational technology. It is possible that because the present study was not conducted in relation to any faculty professional development program and there is no state or accreditation agency requirement that Texas community college faculty have formal pedagogical or technological training (SACSCOC, 2006; TEC §130), some of the low pattern coefficients for some items, the lack of discriminant validity of the TK, TCK, and TPK subscales, and negative and insignificant implied factor correlations between PK and the TK-related constructs affected the results.

Because the PK items are learner centered, they may be problematic in the CC–TSML sample. Since neither law or accreditation policies (SACSCOC, 2006; TEC §130) require Texas community college faculty to have formal pedagogical instruction, it is possible that the sample in the present research conflates some pedagogical practices leading to low factor loadings with "group work" items (PK_5 and PK_6) and "challenging tasks" in PK_1. The CC–TSML sample self-reports that (a) 61.3% have six or more college credits in teaching methods or pedagogy, (b) 71.1% have not been certified to teach at the high school level in the last 15 years, and (c) 61.1% of them are aged 50 or older. It may be possible that we are seeing the results of faculty who have been formally trained in teaching methods and pedagogical practices prior to the focus on learner-centered principles, a concept that was not fully developed by the APA until 1997.

The TK subscale is a limitation in this sample. Most TK items do not seem to resonate with Texas community college professors. Most TK items have low pattern coefficients with the exceptions of TK_3 (“I am able to use online collaboration tools”), TK_4 (“I am able to use online communication tools”), and TK_5 (“I am able to use online note-taking tools”). Items TK_3 to TK_7 use the question construction “I am able to use online _________________ tools,” which may be the cause of some local fit issues. TK items should be reconsidered for the community college population.

## Suggestions for Future Research

Since basic demographics for postsecondary faculty are lacking, one direction for future research is to conduct state- and national-level institution-reported demographics research including gender, standardized ethnicities, birth year, highest degree obtained, organizational tenure, discipline, transcripted credits in teaching methods, and transcripted credits in educational technology or technology integration.

The TK subscale should be revised with an expert committee of community college faculty and instructional designers. This study’s expert committee reviewed the items from the Koh et al. (2014) study with the goal of vetting them for use in community college faculty. Their purpose was not to create “better” questions but rather to ensure the existing questions made sense for community college faculty. Now that the existing TK questions’ performance has been evaluated, future researchers can test new TK items.

To date, no invariance, multi-group, or structural equation modeling of data from postsecondary samples has been conducted. Invariance testing and multi-group modeling between genders, employment status, age, and institution size may provide some additional insight into the data. This study purposefully ignored the clustering of the data (e.g., individuals within institutions; Heck, 2001) in the CFA process; consequently, it is possible that honoring that structure may provide insights into the data not possible when analyzed at the “microlevel” (Heck, 2001, p. 91).

## Summary

The CC–TSML is the only TPACK survey instrument that has been tested in a large sample of U.S. postsecondary faculty. The CC–TSML demonstrated pattern coefficient issues with many of the TK subscale items. In addition, it showed some convergent validity issues related to those TK items and some discriminant validity issues with other TK-related constructs. Even with these issues, the CC–TSML demonstrated good model fit for the 7-factor correlated model.

The present research was limited to Texas community college faculty and by a sample skewed to full-time White female faculty when the reality of the Texas community college population is part time, White, and male. The use of self-report data from a sample in which pedagogical and technological knowledge is not required under state law or accreditation standards with no professional development or theoretical context may also limit the results. PK items focus on learner-centered pedagogies with which Texas community college faculty may not be well-schooled. The TK items failed to perform well in this sample.

Future research suggestions include continued study of the larger U.S. postsecondary professorate. A lack of complete demographics in this population makes it difficult to compare samples to populations. The TK items should be re-evaluated and new items tested with postsecondary faculty. Invariance, multi-group, and structured equation modeling of TPACK in postsecondary faculty is also suggested.

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# Appendix A: TPACK Studies Identified in Scientific Literature Review Process

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# Appendix B. Public Information Act Requests

The Texas Public Information Act (PIA) allows members of the public to ask for and receive information from our public entities. For additional information on the Texas Public Information Act, please see the Public Information Act Handbook 2018 (https://www.texasattorneygeneral.gov/files/og/PIA_handbook_2018.pdf).

A list of all 50 community college districts and their presidents was collected from the Texas Association of Community Colleges website in the spring of 2017 (http://www.tacc.org/pages/texas-colleges) and verified against the individual college's websites. Email addresses for each of the college presidents was acquired either from the college's website or by calling the college president's office and asking for it.

A special Gmail account was set-up to make the PIA request, receive data, and answer questions from presidents or their designees. From the designated email account, the PIA requests were sent to each community college's president asking for a comma-seperated value file of the official school email address of all active faculty, coded for full-time (FT) or part-time (PT) teaching status (see email text below). The researcher's legal name, home address, and personal phone number were included to preclude institutions from delaying the fulfillment of the request. Under the Texas Public Information Act, entitites may ask for this information.

Follow-up email or phone calls were made to any college presidents who did not respond within a week. All questions were answered promptly. All 50 community college districts responded within the requested time frame (4 – 6 weeks) resulting in the acquisition of 33,871 email addresses (see Appendix C).

Under the Public Information Act of Texas, all of the colleges could have charged a reasonable fee for the information; however, only three small colleges chose to do so with a total cost of approximately $65.00.

Through the PIA requests, this researcher was able to acquire almost 34,000 email addresses. THECB (2017) data from Fall 2015 indicates there are over 43,000 faculty in Texas. This researcher suspects that the difference may be due, in part, to under-reporting email addresses of part-time faculty who are also employed at their institutions as full-time staff.

*Public Information Act Request Email Text*

Dear President <LastName>,

Pursuant to the Texas Public Information Act, I am requesting a comma separated value (CSV) file of full email addresses for all current faculty employed at <College> and coded by their full- or part-time status.

Example:

| Email | Status |
|---|---|
| username@college.edu | FT |
| faculty@college.edu | PT |

When the information is collected into a CSV, please email it to me at <special Gmail address> I am expecting to receive the data by Friday, November 17, 2017.

If you or your designees have any questions, please email me at <special Gmail address> or call me at <personal phone number>. Please leave a voicemail if I am unavailable to answer the call.

Best Regards,

Kristin C. Scott
<special Gmail address>
Home Address
City, TX Zip Code
<personal phone number>

Appendix C. Faculty Email Addresses from Texas Community Colleges

| Texas Community Colleges | FT | PT | Total |
|---|---|---|---|
| Alamo Community Colleges | 944 | 1,377 | 2,321 |
| Alvin Community College | 110 | 285 | 395 |
| Amarillo College | 242 | 190 | 432 |
| Angelina College | 81 | 269 | 350 |
| Austin Community College | 629 | 1,310 | 1,939 |
| Blinn College | 230 | 138 | 368 |
| Brazosport College | 92 | 220 | 312 |
| Central Texas College | 158 | 427 | 585 |
| Cisco College | 88 | 95 | 183 |
| Clarendon College | 52 | 51 | 103 |
| Coastal Bend College | 185 | 150 | 335 |
| College of the Mainland[a] | — | — | 105 |
| Collin County Community College | 410 | 779 | 1,189 |
| Dallas County Community College District | 716 | 1,318 | 2,034 |
| Del Mar College | 339 | 250 | 589 |
| El Paso Community College | 460 | 833 | 1,293 |
| Frank Phillips College | 37 | 22 | 59 |
| Galveston College | 54 | 40 | 94 |
| Grayson College | 107 | 108 | 215 |
| Hill College | 85 | 123 | 208 |
| Houston Community College | 1,479 | 2,441 | 3,920 |
| Howard College | 116 | 60 | 176 |
| Kilgore College | 147 | 131 | 278 |
| Laredo Community College | 191 | 146 | 337 |
| Lee College | 195 | 279 | 474 |
| Lone Star College | 939 | 3,192 | 4,131 |
| McLennan Community College | 218 | 196 | 414 |
| Midland College | 152 | 128 | 280 |
| Navarro College | 144 | 245 | 389 |
| North Central Texas College | 147 | 264 | 411 |
| Northeast Texas Community College | 68 | 77 | 145 |
| Odessa College | 122 | 168 | 290 |
| Panola College | 69 | 53 | 122 |
| Paris Junior College | 87 | 94 | 181 |
| Ranger College[a] | — | — | 146 |
| San Jacinto Community College | 539 | 759 | 1,298 |
| South Plains College | 273 | 161 | 434 |
| South Texas College | 629 | 470 | 1,099 |
| Southwest Texas Junior College | 131 | 46 | 177 |
| Tarrant County College | 743 | 2,694 | 3,437 |

| Texas Community Colleges | FT | PT | Total |
|---|---|---|---|
| Temple College | 126 | 156 | 282 |
| Texarkana College | 94 | 67 | 161 |
| Texas Southmost College | 107 | 70 | 177 |
| Trinity Valley Community College | 154 | 26 | 180 |
| Tyler Junior College | 297 | 356 | 653 |
| Vernon College | 76 | 109 | 185 |
| Victoria College | 89 | 21 | 110 |
| Weatherford College | 141 | 293 | 434 |
| Western Texas College | 36 | 46 | 82 |
| Wharton County Junior College | 178 | 181 | 359 |
| Total Community College Faculty Email Addresses | 12,706 | 20,914 | 33,871 |

*Note*. a – Email addresses were not coded for full- or part-time status.

## Appendix D. Item Comparison between Chai et al., 2013 and Koh et al., 2014

| **Chai, Ng, Li, Hong, & Koh, 2013** | | **Koh, Chai, & Tsai, 2014** | |
|---|---|---|---|
| *Content Knowledge* | | *Content Knowledge* | |
| CK1 | I have sufficient knowledge about my teaching subject. | CK1 | I have sufficient knowledge about my **first teaching subject (CS1).** |
| CK2 | I can think about the content of my teaching subject like a subject matter expert. | CK2 | I can think about the content of my **first teaching subject (CS1)** like a subject matter expert. |
| CK3 | I am able to gain deeper understanding about the content of my teaching subject on my own. | CK3 | I am able to develop deeper understanding about the content of **my first teaching subject (CS1)**. |
| CK4 | I am confident to teach the subject matter. | | |
| *Pedagogical Content Knowledge* | | *Pedagogical Content Knowledge* | |
| PCK1 | Eliminated—low factor loading | PCK1 | Without using technology, I can address the common misconceptions my students have for my **first teaching subject (CS1)**. |
| PCK2 | Eliminated—low factor loading | PCK2 | Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my **first teaching subject (CS1)**. |
| PCK3 | Without using technology, I can help my students to understand the content knowledge of my teaching subject through various ways. | PCK3 | Without using technology, I can help my students to understand the content knowledge of my **first teaching subject (CS1)** through various ways. |
| PCK4 | Without using technology, I can address the common learning difficulties my students have for my teaching subject. | | |

|  | Chai, Ng, Li, Hong, & Koh, 2013 |  | Koh, Chai, & Tsai, 2014 |
|---|---|---|---|
| PCK5 | Without using technology, I can facilitate meaningful discussion about the content students are learning in my teaching subject. |  |  |
| PCK6 | Without using technology, I can engage students in solving real-world problems related to my teaching subject. |  |  |
| PCK7 | Eliminated—low factor loading |  |  |
| PCK8 | Without using technology, I can support students to manage their learning of content for my teaching subject. |  |  |
| *Pedagogical Knowledge* |  | *Pedagogical Knowledge* |  |
| PK1 | I am able to stretch my students' thinking by creating challenging tasks for them. | PK1 | I am able to stretch my students' thinking by creating challenging tasks for them. |
| PK2 | I am able to guide my students to adopt appropriate learning strategies. | PK2 | I am able to guide my students to adopt appropriate learning strategies. |
| PK3 | I am able to help my students to monitor their own learning. | PK3 | I am able to help my students to monitor their own learning. |
| PK4 | I am able to help my students to reflect on their learning strategies. | PK4 | I am able to help my students to reflect on their learning strategies. |
| PK5 | Eliminated—low factor loading | PK5 | I am able to plan group activities for my students. |
| PK6 | I am able to guide my students to discuss effectively during group work. | PK6 | I am able to guide my students to discuss effectively during group work. |

| Chai, Ng, Li, Hong, & Koh, 2013 | | Koh, Chai, & Tsai, 2014 | |
|---|---|---|---|
| *Technological Pedagogical Content Knowledge* | | *Technological Pedagogical Content Knowledge* | |
| TPCK1 | I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools (e.g., Google sites, discussion forums). | TPACK1 | I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools. (e.g., Google sites, CoveritLive). |
| TPCK2 | Eliminated—low factor loading | TPACK2 | I can design authentic problems about the content knowledge and represent them through computers to engage my students. |
| TPCK3 | I can structure activities to help students to construct different representations of the content knowledge using appropriate ICT tools (e.g., Webspiration, Mindmaps, Wikis). | TPACK3 | I can structure activities to help students to construct different representations of content knowledge using appropriate ICT tools (e.g., Webspiration, Mindmeister, Wordle). |
| TPCK4 | I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g., Blogs, Webquests). | TPACK4 | I can create self-directed learning activities of the content knowledge with appropriate ICT tools (e.g., Blog, Webquest). |
| TPCK5 | I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g., simulations, web-based materials). | TPACK5 | I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g., simulations, web-based materials). |
| TPCK6 | I can design lessons that appropriately integrate content, technology, and pedagogy for student-centered learning. | | |

| **Chai, Ng, Li, Hong, & Koh, 2013** | | **Koh, Chai, & Tsai, 2014** | |
|---|---|---|---|
| *Technological Content Knowledge* | | *Technological Content Knowledge* | |
| TCK1 | I can use the software that are created specifically for my teaching subject (e.g., e-dictionary/corpus for language; geometric sketchpad for maths; data loggers for science). | TCK1 | I can use the software that are created specifically for my **first teaching subject (CS1)** (e.g., e-dictionary/corpus for language; geometric sketchpad for maths; data loggers for science) |
| TCK2 | I know about the technologies that I have to use for the research of content of my teaching subject. | TCK2 | I know about the technologies that I have to use for the research of content of **first teaching subject (CS1).** |
| TCK3 | I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my teaching subject. | TCK3 | I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my **first teaching subject (CS1)**. |
| TCK4 | I can use specialized software to perform inquiry about my teaching subject. | | |
| *Technological Pedagogical Knowledge* | | *Technological Pedagogical Knowledge* | |
| TPK1 | I am able to use technology to introduce my students to real world scenarios. | TPK1 | I am able to use technology to introduce my students to real-world scenarios. |
| TPK2 | Eliminated—low factor loading | TPK2 | I am able to facilitate my students to use technology to find more information on their own. |
| TPK3 | I am able to facilitate my students to use technology to plan and monitor their own learning. | TPK3 | I am able to facilitate my students to use technology to plan and monitor their own learning. |
| TPK4 | I am able to facilitate my students to use technology to construct different forms of knowledge representation. | TPK4 | I am able to facilitate my students to use technology to construct different forms of knowledge representation. |
| TPK5 | I am able to facilitate my students to collaborate with each other using technology. | TPK5 | I am able to facilitate my students to collaborate with each other using technology. |

| **Chai, Ng, Li, Hong, & Koh, 2013** | | **Koh, Chai, & Tsai, 2014** | |
|---|---|---|---|
| *Technological Knowledge* | | *Technological Knowledge* | |
| TK1 | ~~I have the technical skills to use computers effectively~~. | TK1 | I am able to create web pages. |
| TK2 | ~~I can learn technology easily.~~ | TK2 | I am able to use social media (e.g., blogs, wikis, Facebook). |
| TK3 | ~~I know how to solve my own technical problems when using technology.~~ | TK3 | I am able to use collaboration tools (e.g., Google sites, CoveritLive). |
| TK4 | ~~I keep up with important new technologies~~. | TK4 | I am able to use communication tools (e.g., VoiceThread, Podcast). |
| | | TK5 | I am able to use online sticky notes (e.g., Diigo, Wallwisher). |
| | | TK6 | I am able to use mind tools (e.g., Webspiration, Mindmeister). |
| | | TK7 | I am able to use visualization tools (e.g., Wordle, Quizlet). |

Appendix E. Item Comparison between Koh et al., 2014 and CC–TSML

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| *Technological Knowledge* | | | |
| TK1 | I am able to create web pages. | I am able to create web pages. | No Change |
| TK2 | I am able to use social media (e.g., blogs, wikis, Facebook). | I am able to use social media ~~(e.g., blogs, wikis, Facebook)~~. | • Removed examples that may limit target study population's thinking. |
| TK3 | I am able to use collaboration tools (e.g., Google sites, CoveritLive). | I am able to use **online** collaboration tools ~~(e.g., Google sites, CoveritLive)~~. | • Added "online" to clarify this item's relationship to online technology in keeping with the original question's examples.<br>• Removed examples that may limit target study population's thinking. |
| TK4 | I am able to use communication tools (e.g., VoiceThread, Podcast). | I am able to use **online** communication tools ~~(e.g., VoiceThread, Podcast)~~. | • Added "online" to clarify this item's relationship to online technology in keeping with the original question's examples.<br>• Removed examples that may limit target study population's thinking. |
| TK5 | I am able to use online sticky notes (e.g., Diigo, Wallwisher). | I am able to use **online note-taking tools** ~~sticky notes (e.g., Diigo, Wallwisher)~~. | • Added "online note-taking tools" to clarify this item's relationship to online technology in keeping with the original question's examples and to reflect skills needed in the target study population.<br>•Removed examples which may limit target study population's thinking |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| TK6 | I am able to use mind tools (e.g., Webspiration, Mindmeister). | I am able to use **online** mind-**mapping** tools ~~(e.g., Webspiration, Mindmeister)~~. | •Revised to "online mind-mapping tools" to clarify this is related to online technology in keeping with the original question's examples and to better reflect the skills needed in the target study population.<br>•Removed examples which may limit target study population's thinking |
| TK7 | I am able to use visualization tools (e.g., Wordle, Quizlet). | I am able to use **online** visualization tools (e.g., Wordle, Quizlet). | •Added "online note-taking tools" to clarify this item's relationship to online technology in keeping with the original question's examples and to better reflect the skills needed in the target study population.<br>•Retained examples as "visualization tools" may not be enough to help the members of the target study population understand the question. |
| *Content Knowledge* | | | |
| CK1 | I have sufficient knowledge about my first teaching subject (CS1). | I have sufficient knowledge about my ~~first~~ teaching subject ~~(CS1)~~. | •Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| CK2 | I can think about the content of my first teaching subject (CS1) like a subject matter expert. | I can think about the content of my ~~first~~ teaching subject ~~(CS1)~~ like a subject matter expert. | •Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| CK3 | I am able to develop deeper understanding about the | I am able to develop **a** deeper understanding about the content of my ~~first~~ teaching subject ~~(CS1)~~. | • Added "a" to match the singular "understanding" in the sentence.<br>•Removed references to "first teaching subject" |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| | content of my first teaching subject (CS1). | | or curriculum subject to reflect target study population's generally singular area of expertise. |
| *Pedagogical Knowledge* | | | |
| PK4 | I am able to help my students to reflect on their learning strategies. | I am able to help my students to reflect on their learning strategies. | •No Change |
| PK3 | I am able to help my students to monitor their own learning. | I am able to help my students to monitor their own learning. | •No Change |
| PK6 | I am able to guide my students to discuss effectively during group work. | I am able to guide my students **to engage in effective discussion** ~~to discuss effectively~~ during group work. | •Revised to "to engage in effective discussion" to match question construction of other questions in this construct. |
| PK2 | I am able to guide my students to adopt appropriate learning strategies. | I am able to guide my students to adopt appropriate learning strategies. | •No Change |
| PK5 | I am able to plan group activities for my students. | I am able to plan group activities for my students. | •No Change |
| PK1 | I am able to stretch my students' thinking by creating challenging tasks for them. | I am able to stretch my students' thinking by creating challenging tasks for them. | •No Change |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| *Pedagogical Content Knowledge* | | | |
| PCK2 | Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my first teaching subject (CS1). | Without using technology, I know how to select effective teaching approaches to guide student thinking and learning in my ~~first~~ teaching subject ~~(CS1)~~. | •Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| PCK3 | Without using technology, I can help my students to understand the content knowledge of my first teaching subject (CS1) through various ways. | Without using technology, I can help my students to understand the content knowledge of my ~~first~~ teaching subject ~~(CS1)~~ through various ways. | •Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| PCK1 | Without using technology, I can address the common misconceptions my students have for my first teaching subject (CS1). | Without using technology, I can address the common misconceptions my students have **about**~~for~~ my ~~first~~ teaching subject ~~(CS1)~~. | •Changed "for" to "about"; "for" is used to indicate expressing a purpose or benefit, "about" is used when referencing something that is ordinary or general (Bullock, Brody, & Weinberg, 2014).<br>•Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| *Technological Content Knowledge* | | | |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| TCK2 | I know about the technologies that I have to use for the research of content of first teaching subject (CS1). | I know about the technologies **that are availablefor me**~~I have~~ to use for the research of content of ~~first~~ teaching subject ~~(CS1)~~. | •Changed "I have" to "that are available to me" to prevent readers from reading "have" as a command.<br>•Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| TCK3 | I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my first teaching subject (CS1). | I can use appropriate technologies (e.g., multimedia resources, simulation) to represent the content of my ~~first~~ teaching subject ~~(CS1)~~. | •Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| TCK1 | I can use the software that are created specifically for my first teaching subject (CS1). (E.g., e-dictionary/corpus for language; geometric sketchpad for maths; data loggers for science) | I can use the software **programs** that are created specifically for my ~~first~~ teaching subject ~~(CS1)~~. ~~(E.g., e-dictionary/corpus for language; geometric sketchpad for maths; data loggers for science)~~ | •Added "programs" to be sure that the target study population to clarify meaning of the original question.<br>•Removed references to "first teaching subject" or curriculum subject to reflect target study population's generally singular area of expertise. |
| *Technological Pedagogical Knowledge* | | | |
| TPK3 | I am able to facilitate my students to use technology to plan and monitor their own learning. | I am able to facilitate my students**'**~~to~~ use **of** technology to plan and monitor their own learning. | •Added apostrophe to "students" to show plural possession of the technology use.<br>•Changed "students to use technology" to "students' use of technology" to clarify what is being done and who is doing it. |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| TPK4 | I am able to facilitate my students to use technology to construct different forms of knowledge representation. | I am able to facilitate my students**'**~~to~~ use **of** technology to construct different forms of knowledge representation. | •Added apostrophe to "students" to show plural possession of the technology use.<br>•Changed "students to use technology" to "students' use of technology" to clarify what is being done and who is doing it. |
| TPK5 | I am able to facilitate my student sto collaborate with each other using technology. | I am able to facilitate my students' **collaboration**~~to collaborate~~ with each other using technology. | •Added apostrophe to "students" to show plural possession of the technology use.<br>•Changed "students to collaborate" to "students' collaboration" to clarify what is being done and who is doing it. |
| TPK1 | I am able to use technology to introduce my students to real world scenarios. | I am able to use technology to introduce my students to real world scenarios. | •No Change |
| TPK2 | I am able to facilitate my students to use technology to find more information on their own. | I am able to facilitate my students**'**~~to~~ use **of** technology to find more information on their own. | •Added apostrophe to "students" to show plural possession of the technology use.<br>•Changed "students to use technology" to "students' use of technology" to clarify what is being done and who is doing it. |
| *Technological Pedagogical Content Knowledge* | | | |
| TPACK1 | I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools (e.g., Google Sites, CoveritLive). | I can formulate in-depth discussion topics about the content knowledge and facilitate students' online collaboration with appropriate tools ~~(e.g., Google Sites, CoveritLive)~~. | •Remove examples which may limit target study population's thinking |

| Item Number | Koh et al., 2014 TSML Instrument | CC–TSML Instrument | Rationale for Change |
|---|---|---|---|
| TPACK3 | I can structure activities to help student construct different representations of content knowledge using appropriate ICT tools (e.g., Webspiration, Mindmeister, Wordle). | I can structure activities to help student construct different representations of content knowledge using appropriate **digital technology**~~ICT~~ tools ~~(e.g., Webspiration, Mindmeister, Wordle)~~. | •Changed "ICT" to "digital technology" to better reflect the common terminology of the target study population.<br>•Remove examples which may limit target study population's thinking |
| TPACK4 | I can create self-directed learning activities of the content knowledgewith appropriate ICT tools (e.g., Blog, Webquest). | I can create self-directed learning activities of the content knowledge with appropriate **digital technology**~~ICT~~ tools ~~(e.g., Blog, Webquest)~~. | •Changed "ICT" to "digital technology" to better reflect the common terminology of the target study population.<br>•Remove examples which may limit target study population's thinking |
| TPACK5 | I can design inquiry activities to guide students to make sense of the content knowledge with appropriate ICT tools (e.g., simulations, web-based materials). | I can design inquiry-based activities to guide students to make sense of the content knowledge with appropriate **digital technology**~~ICT~~ tools (e.g., simulations, web-based materials). | •Changed "ICT" to "digital technology" to better reflect the common terminology of the target study population.<br>•Retained examples to reflect original question intent. |
| TPACK2 | I can design authentic problems about the content knowledge and represent them through computers to engage my students. | I can design authentic problems about the content knowledge and represent them through **digital technology**~~computers~~ to engage my students. | •Changed "ICT" to "digital technology" to better reflect the common terminology of the target study population. |

*Note.* Items in bold indicate an addition. Items with strikethrough indicate a deletion.

Appendix F. Participant Invitation and Reminder Emails

**Recruiting email draft:**
Respond to: Kristin C. Scott
Respond to email: kscott10@patriots.uttyler.edu

Subject: Texas Community College Faculty Needed!

# Do you know about *60x30TX*,

## the Texas Higher Education Coordinating Board's strategic plan for higher education?

Hello! I am contacting you as a fellow Texas community college faculty member and *60x30TX* is going to impact every one of us!

Because *60x30TX* will have such a broad impact, I am using it to drive my doctoral dissertation research. In my studies, I am trying to find a short, simple survey faculty can use to determine how well their knowledge, skills, and abilities line up with the focal points of *60x30TX*. The only way to know if it is statistically valid and reliable is to test it with you!

**You have been specially selected from all the community college faculty in Texas to participate in this test of the survey so it is important that you do not share the survey link below**.

***Your participation is, of course, voluntary, anonymous, and highly valued!***

This online survey will only take you about 8 – 10 minutes and has been approved by The University of Texas at Tyler Internal Review Board. Click the link below to access the survey or you can copy and paste the link into your browser.

[Qualtrics link]

You will receive two reminder emails, one later this week and one next week. No other emails will be sent to clutter up your inbox!

Many Thanks,

Kristin C. Scott, M.Ed.
Doctoral Candidate
UT Tyler Department of Human Resource Development

**Reminder 1 email draft:**
Respond to: Kristin C. Scott
Respond to email: kscott10@patriots.uttyler.edu

Subject: Reminder: Texas Community College Faculty Still Needed!

# *60x30TX* will impact you!

This is your first reminder email to participate in the study of a simple and short (only 8 – 10 minutes) survey designed to allow you to anonymously self-assess how well your knowledge, skills, and abilities align with some of the Texas Higher Education Coordinating Board's strategic plan targets.

**Remember, you have been specially selected to participate so your input is extremely valuable!**

Just by way of reminder, I am a Texas community college faculty member conducting my doctoral research. In that research, I am testing a survey to discover if it is both statistically valid and reliable. I can only do that with your participation.

Your participation is highly valued but is, of course, voluntary and anonymous.

This online survey has been approved by The University of Texas at Tyler Internal Review Board. Click the link below to access the survey or you can copy and paste the link into your browser.

[Qualtrics link]

Please do not share this link with other faculty. Only you and select other Texas community college faculty have been invited to participate.

You will receive only one more reminder email before the study closes.

Best Regards,

Kristin C. Scott, M.Ed.
Doctoral Candidate
UT Tyler Department of Human Resource Development

**Reminder 2 email draft:**
Respond to: Kristin C. Scott
Respond to email: kscott10@patriots.uttyler.edu

Subject: Last Call

# Last Call to Participate!

**The *60x30TX* strategic plan from the Texas Higher Education Coordinating Board will have lasting impacts across the state and at your institution.**

I am a community college professor just like you and I am conducting my doctoral research on how *60x30TX* may impact you. In my studies, I am testing a short, simple, self-assessment survey that faculty can use to see how their current knowledge, skills, and abilities line up with the *60x30TX* plan.

**Remember, you have been specially selected to participate in this study so your participation is extremely valuable! Please do not share this link with others.**

This voluntary, anonymous, online survey will only take about 8 – 10 minutes of your time and has been approved by The University of Texas at Tyler Internal Review Board. Click the link below to access the survey or you can copy and paste the link into your browser.

[Qualtrics link]

The study closes in just a few days so this is your last reminder to participate!

Thank You and Best Regards,

Kristin C. Scott, M.Ed.
Doctoral Candidate
UT Tyler Department of Human Resource Development

# Appendix G. Informed Consent Statement

Welcome!

You have been invited to participate in the study titled, *Community College TPACK Survey of Meaningful Learning*. The purpose of this study is to investigate the statistical validity and reliability of the data generated using this self-assessment survey with Texas community college faculty. Your participation is completely anonymous, voluntary, and if you begin participation and choose to not complete it, you are free to not continue without any adverse consequences.

<u>If you agree to participate, you are asked to:</u>
Complete an anonymous, voluntary, online survey that is estimated to take between 8 and 10 minutes.

There are no known risks to this study, other than becoming a little tired of answering the questions. If this happens, you are free to discontinue participation by closing your browser window. Potential benefits to this study include helping you discover areas of strength and areas on which to focus your professional development and it may assist colleges in determining which professional development activities will be most beneficial to their faculty.

Consent Statement
I know my responses to the questions are anonymous. If I need to ask questions about this study, I can contact the principle researcher, Kristin C. Scott at kscott10@patriots.uttyler.edu, or, if I have any questions about my rights as a research participant, I can contact Dr. Gloria Duke, Chair of the UT Tyler Institutional Review Board at gduke@uttyler, or 903-566-7023.

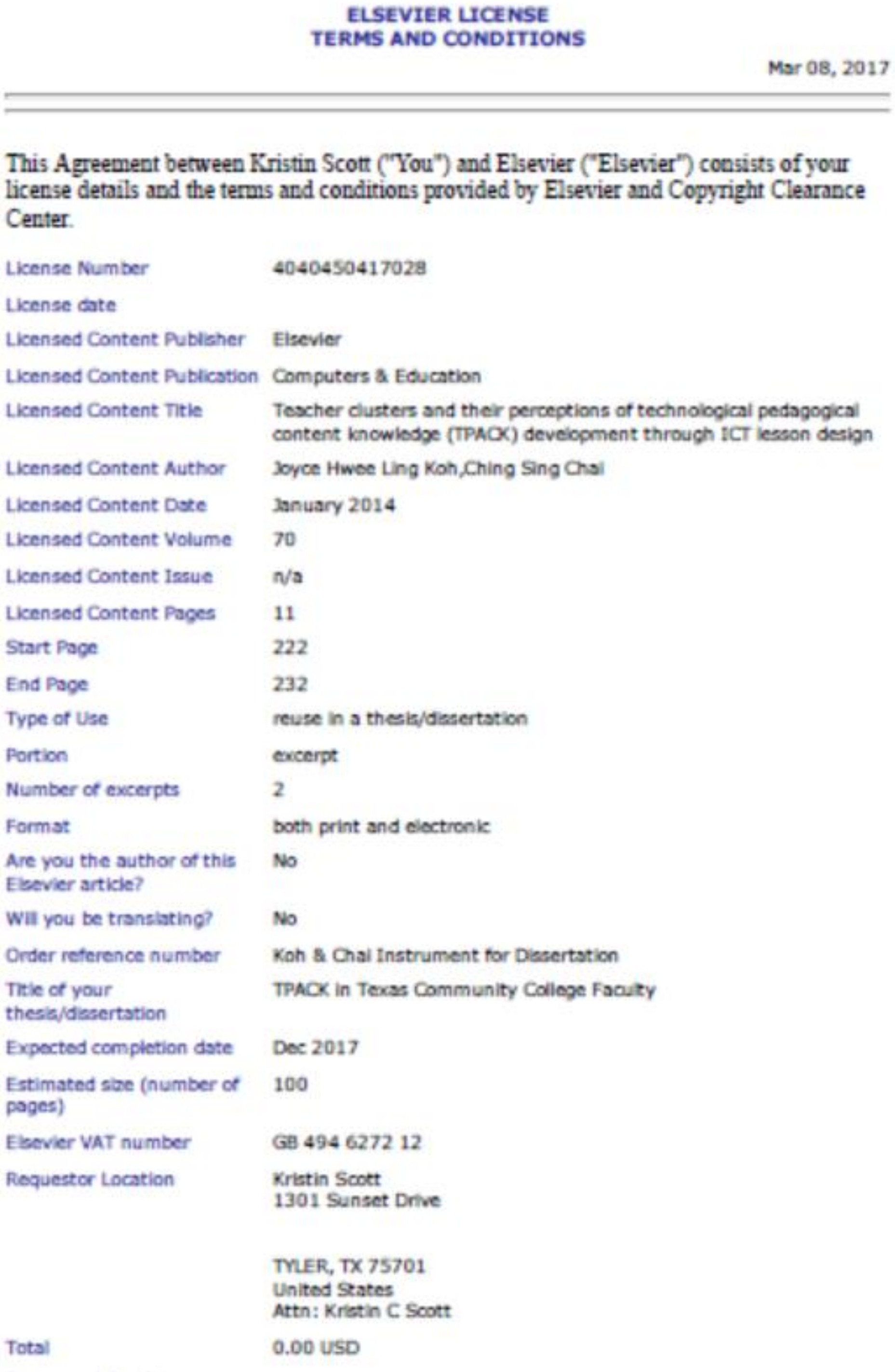
I have read and understood what has been explained to me. If I choose to participate in this study, I will click “Yes” in the box below and proceed to the survey. If I choose to not participate, I will click “No” in the box.

Yes, I choose to participate in this study.

No, I decline to participate.

Link to live survey: <u>https://uttyler.az1.qualtrics.com/jfe/form/SV_9BL5YMof8sXg0OV</u>
<u>*(this will be updated when we agree on the text of the consent)*</u>

# Appendix H. Permission to Use TPACK Survey



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**TERMS AND CONDITIONS**

Mar 08, 2017

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| Expected completion date | Dec 2017 |
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| Requestor Location | Kristin Scott<br>1301 Sunset Drive<br><br>TYLER, TX 75701<br>United States<br>Attn: Kristin C Scott |
| Total | 0.00 USD |

# Appendix I. Permission to Use ATTCB

4/14/2017 12:43 PM

**Kristin Scott**

**From:** Brian K. Miller <bkmiller@txstate.edu>
**Sent:** Tuesday, February 21, 2017 4:42 PM
**To:** Kristin Scott
**Cc:** Marcia Simmering
**Subject:** Re: Permission to Use
**Attachments:** Miller & Chiodo (2008) Attitudes Toward the Color Blue.pdf; ATT00001.htm

Ms. Scott,
Yes, of course. I've attached a copy of the scale and note its proper citation below.

Miller, B.K., & Chiodo, B. (2008). Academic entitlement: Adapting the equity preference questionnaire for a university setting. Presented at the annual conference of the Southern Management Association in Clearwater Beach, FL.

I've cc'ed a colleague on this reply with whom I'm working on a full-blown scale development paper for ATCB. We'd love to get your feedback on it when we're done.

Regards,
Brian

---

Brian K. Miller, Ph.D., M.Ed.
Professor of Management

Texas State University
545 McCoy Hall
San Marcos, TX 78666

Tel: 512-245-7179
Fax: 512-245-2850

Associate Editor of the *Journal of Managerial Psychology*

My YouTube Channel: [https://www.youtube.com/c/DrBrianKMiller](https://www.youtube.com/c/DrBrianKMiller)

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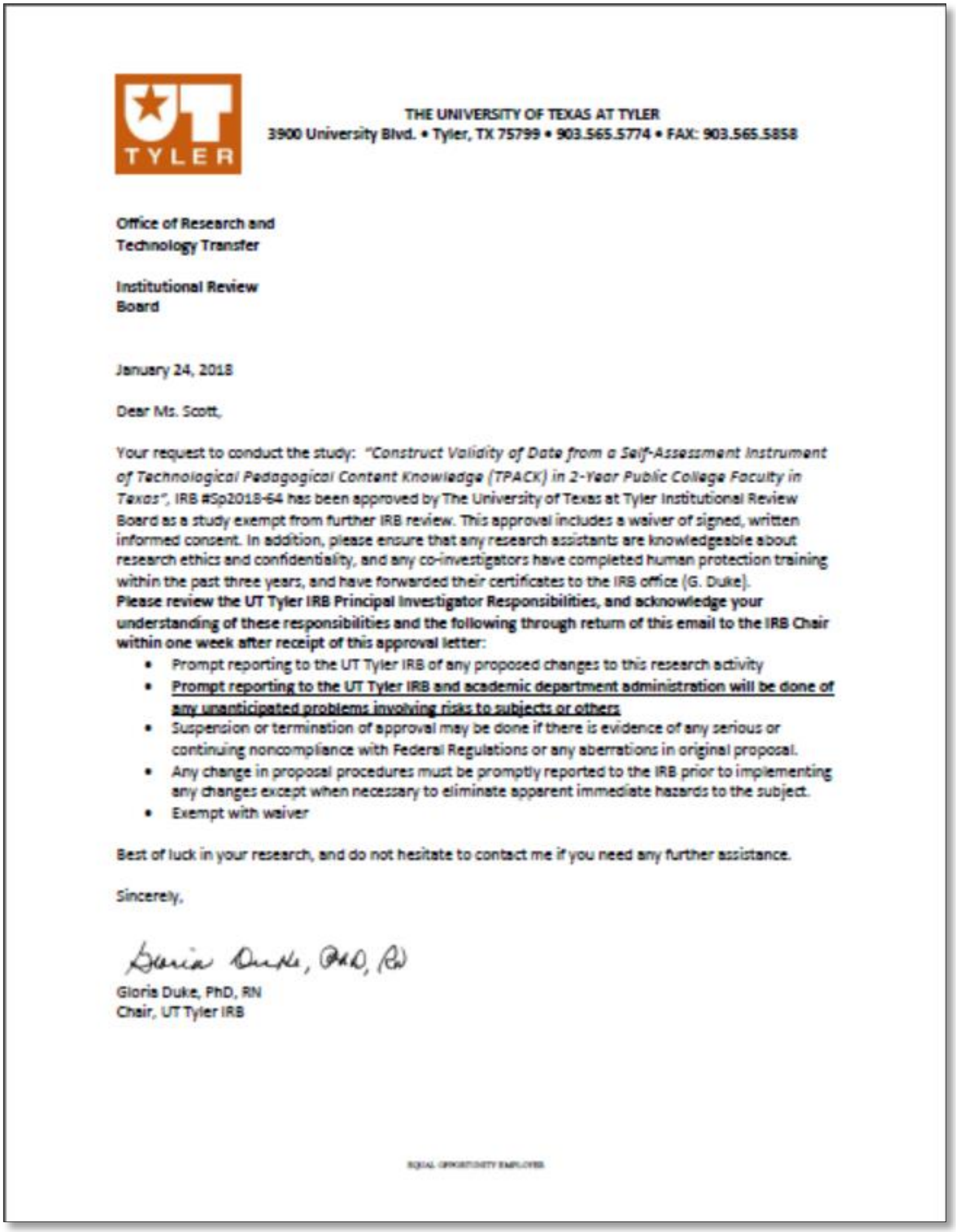
# Appendix J. IRB Approval



THE UNIVERSITY OF TEXAS AT TYLER
3900 University Blvd. • Tyler, TX 75799 • 903.565.5774 • FAX: 903.565.5858

**Office of Research and Technology Transfer**

**Institutional Review Board**

January 24, 2018

Dear Ms. Scott,

Your request to conduct the study: *"Construct Validity of Data from a Self-Assessment Instrument of Technological Pedagogical Content Knowledge (TPACK) in 2-Year Public College Faculty in Texas"*, IRB #Sp2018-64 has been approved by The University of Texas at Tyler Institutional Review Board as a study exempt from further IRB review. This approval includes a waiver of signed, written informed consent. In addition, please ensure that any research assistants are knowledgeable about research ethics and confidentiality, and any co-investigators have completed human protection training within the past three years, and have forwarded their certificates to the IRB office (G. Duke).
**Please review the UT Tyler IRB Principal Investigator Responsibilities, and acknowledge your understanding of these responsibilities and the following through return of this email to the IRB Chair within one week after receipt of this approval letter:**

- Prompt reporting to the UT Tyler IRB of any proposed changes to this research activity
- **Prompt reporting to the UT Tyler IRB and academic department administration will be done of any unanticipated problems involving risks to subjects or others**
- Suspension or termination of approval may be done if there is evidence of any serious or continuing noncompliance with Federal Regulations or any aberrations in original proposal.
- Any change in proposal procedures must be promptly reported to the IRB prior to implementing any changes except when necessary to eliminate apparent immediate hazards to the subject.
- Exempt with waiver

Best of luck in your research, and do not hesitate to contact me if you need any further assistance.

Sincerely,

Gloria Duke, PhD, RN

Gloria Duke, PhD, RN
Chair, UT Tyler IRB

EQUAL OPPORTUNITY EMPLOYER