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Measuring TPACK in 2-Year Public College Faculty:
An HRM Assessment Tool

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ABSTRACT

Two-year public colleges educate more than 50% of all U.S. undergraduates, yet graduation rates (29%) fall far below their 4-year counterparts (63%). It is critical for students of 2-year public institutions that their faculty have the appropriate knowledge, skills, and abilities (KSAs) to effectively guide students toward graduation. This study uses technological pedagogical content knowledge (TPACK) theory to evaluate faculty KSAs. Exploratory and confirmatory factor analyses are used to demonstrate reliability, validity, and the 7-factor structure of the data. This instrument may be useful in pre-employment KSA assessment for potential new faculty, as well as identifying professional development opportunities for incumbent faculty.

KEYWORDS

Community College, Employee Assessment, Higher Education, Professional Development, Technological Pedagogical Content Knowledge, TPACK

INTRODUCTION

Faculty qualifications at 2-year public colleges are typically based on standards set by outside accreditation agencies, such as the Southern Association of Colleges and Schools—Commission on Colleges (SACS-COC). These standards usually focus on graduate hours or advanced degree completion to determine if content knowledge meets minimum requirements. However, research shows that content knowledge alone is not sufficient to be an effective teacher (Chickering & Gamson, 1996; Levin et al., 2006; Mishra & Koehler, 2006; Wyner, 2014). Many students entering 2-year

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public colleges are academically underprepared or otherwise at-risk of non-completion (CCCSE, 2016; USDoE, 2023a-d; Friedel et al., 2014) and research has proven that learner-centered teaching practices and technology infusion are critical for at-risk students' success (e.g., Bailey et al., 2015; Darling-Hammond et al., 2014).

At this time, there appears to be no commonly used objective assessments of person-job fit by knowledge, skill, and ability (KSA) in the post-secondary academy. This report seeks to discover a cost-efficient self-assessment instrument that 2-year public colleges can use to assess faculty KSAs for person-job fit for the not-yet-employed, or for professional development for incumbents.

In 2021, U.S. public 2-year colleges, also called community colleges, received approximately $485.5 billion dollars in revenue across all sources (USDoE, 2023a). Of that, approximately $73.7 billion dollars came from federal monies; approximately $123.9 billion from state and local funds; and a further $78.4 billion came from tuition and fees (USDoE, 2023a). This makes the 2-year public college system in the United States a bigger revenue generator than the top 50 largest companies by revenue (Horowitz, 2022).

More than half (63%) of all post-secondary students attend a 2-year public college (USDoE, 2023a-d). Community colleges served approximately 7 million students in 2020-2021 while about 11.1 million attended 4-year public colleges (USDoE, 2023b). Graduation data indicate that in 2021, 36.4% of students at 2-year institutions completing their degree or certificate in 150% of the normal time to degree (USDoE, 2023c). However, 4-year public institution data from the same period shows that 60.9% graduated in 150% of normal time to degree. In summary, while most students attending post-secondary school in the United States are attending a 2-year public college, their completion rates are 40.2% lower than their 4-year public college peers. These data indicate the public and student returns on investment (ROI) for 2-year public colleges is lacking. Students and the public seek better ROI for their time and dollars (Carrns, 2021; Horowitz, 2022; Pelletier et al., 2023).

In the education sector, faculty are the first-line workers that help create the product: *graduates*. While faculty cannot create the product alone, their knowledge, skills, and abilities (KSAs) directly impact the ability of their students to complete their studies and graduate. The EDUCAUSE Horizon Report for 2023 identifies key technologies and practices that will impact higher education institutions and faculty. Among those included are micro-credentialing, learner-centered pedagogies and modalities, and new technologies such as predictive AI and personal learning paths (Pelletier et al., 2023). TPACK research associated with student outcomes reinforces the need for high-quality pedagogical practices and the incorporation of technology to support the curriculum. Well-deployed active learning methodologies incorporating the appropriate use of technology have a positive relationship to community college student achievement (Farrelly & Kaplin, 2019; Fuchs & Tsaganea, 2020; Oncu, 2021; Novita et al., 2022).

TPACK research and the development of an instrument can help identify faculty professional development needs to as well as demonstrable efforts to increase ROI through targeted faculty development. Wyner (2014) reminds us that 2-year public colleges that seriously address teaching and learning have more equitable outcomes and higher student salaries after graduation. EDUCAUSE points out that "…it's often the pedagogical practices or the development of…capabilities that offer the most potential" and that there is a "combination effect" when new technologies and new faculty and institutional capabilities are developed (Pelletier et al., 2023, p. 18). This is precisely what TPACK is designed to do (Harris et al., 2017; Heitink et al., 2017).

The 2-Year Public College Landscape in the United States

Community colleges typically serve a larger proportion of the nation's at-risk student population compared to traditional 4-year universities and account for more than one-half of all undergraduate enrollment in the United States (Bailey et al., 2015; CCCSE 2016; Mellow et al., 2011; Shugart, 2016; USDoE, 2023a-d). Students at 2-year intuitions and at-risk students are more likely to be successful when faculty use learner-centered principles and technology (Alshehri, 2020; APA, 1997; Vygotsky, 1978). In 1996, Chickering and Ehrmann stated that active learning and technology were critical to the "seven principles" (Chickering & Gamson, 1987) of quality undergraduate education that include active learning and tight feedback loops.

Learner-centered teaching methodologies infused with technology can help teachers create authentic and engaging learning activities that help students find and create knowledge for themselves (Bain, 2004; Chickering & Gamson, 1987; Osman et al., 2015). Using these types of methodologies can help improve higher-level thinking skills and give students a sense of mastery (Deksissa et al., 2014; O'Banion, 1997). The general technology skills students learn when using common technologies (e.g., Microsoft Teams, Zoom, DropBox), as well as the content-specific technologies necessary for their discipline, help students develop skills that help make them more employable (e.g., Kuh & Schneider, 2008).

Community College Faculty Knowledge, Skills, and Abilities

The importance of technological skill extends beyond teaching and is often crucial to the content being taught and the institution's mission (Levin et al., 2006; Nevarez & Wood, 2010). Incentivizing faculty to regularly up-skill in technology is a common practice at some institutions (Levin et al., 2006). The COVID-19 pandemic and the subsequent closure of physical campuses in the United States during Spring 2020 have underscored the necessity of technology skill in faculty. Community colleges that prioritize learning-centered practices across disciplines ensure that new faculty members are aligned with their approaches during the hiring process (Wyner, 2014, p. 85). These factors highlight the importance of incorporating learner-centered pedagogical knowledge (PK) and technological knowledge (TK) into the KSAs needed in community college faculty for effective teaching (e.g., Alshehri, 2020; Levin et al., 2006; Novita et al., 2022; Wyner, 2014).

Despite the significance of KSAs needed, routine measurement of these constructs in community college faculty cannot be found in the literature (Eddy, 2010; Friedel et al., 2014; Levin et al., 2006; Nevarez & Wood, 2010; SACS-COC, 2006; Scott, 2018, 2020, 2021; Scott & Nimon, 2021; Wyner, 2014). Developing an instrument that can reliably and validly measure these constructs may assist community colleges in aligning person-job fit via KSAs for their faculty. In this study, the authors employ a modified version of an instrument designed to measure all TPACK constructs through a learner-centered lens, an instrument that aligns well with the identified KSAs for community college faculty (Koh, Chai, & Tsai, 2014; Scott & Nimon, 2021).

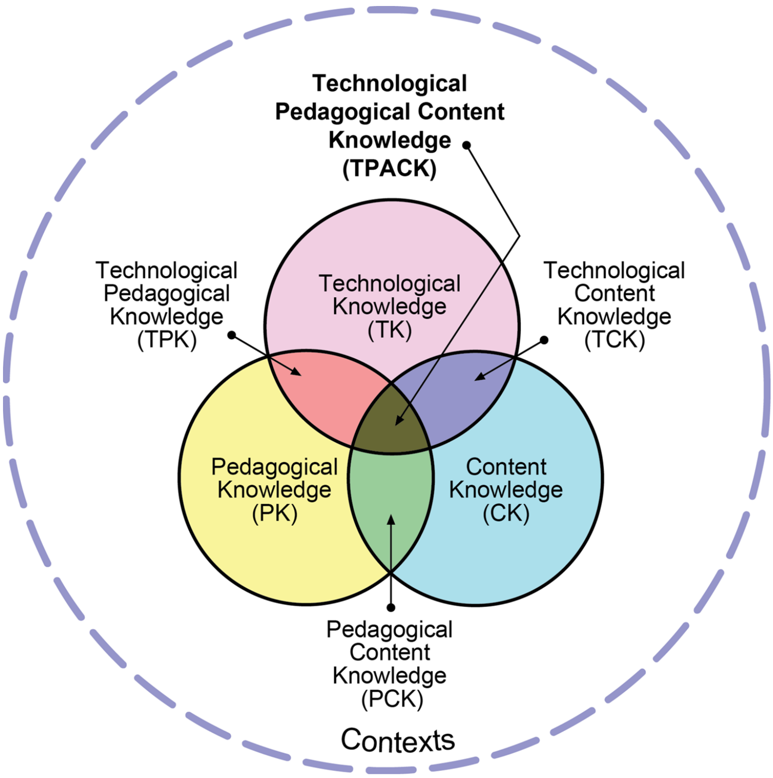
THEORETICAL FRAMEWORK

This study is based on the technological pedagogical content knowledge (TPACK) model developed by Mishra and Koehler (2006). This theory expands on Shulman's (1987) PCK theory and Pierson's (2001) ideas about technological infusion. Mishra and Koehler developed the TPACK theory in 2006 using several years' worth of design experiment study data. Their research included U.S. faculty from every level: primary, secondary, and post-secondary.

Shulman (1987) introduced the idea that teaching is a multifaceted practice using both content and pedagogical knowledge and having the skill to use pedagogies most suited to the content being taught. Pierson (2001) introduced the inclusion of technology into the Shulman (1987) model, but her qualitative study goes no further in model development.

Mishra and Koehler (2006) expand on Shulman's (1987) model and honor Pierson's (2001) contributions with the inclusion of a specific technological knowledge (TK) construct on the initial level. This level also includes content knowledge (CK) and pedagogical knowledge (PK) (see Figure 1). Further, Mishra and Koehler (2006) include intervening constructs of pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK), as well as the final construct: TPACK. The model shown in Figure 1 demonstrates the overlapping and intertwined nature of the constructs.

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



In TPACK theory, Mishra and Koehler (2006) define technology as "digital computers and computer software, artifacts and mechanisms that are new and not yet part of the mainstream" (p. 1023). However, Angeli and Valanides (2009) suggested that Mishra and Koehler's theory needed some refinements. They argued that Shulman's (1987) model had included technology when he included instructional tools in his model (Angeli & Valanides, 2009). Moreover, they suggested a solution: refine the definition of technology to emphasize information and communications technologies (ICT) in combination with the TPACK model. Angeli & Valanides (2009) called it ICT-TPACK. This new theoretical conceptualization of ICT-TPACK focuses on technologies used for effective, possibly innovative, and transformative, teaching practices (Angeli & Valanides, 2009). Angeli and Valanides's (2009) conceptualization of technology has the basis of the measurement instrumentation in the literature.

In 2009, Cox and Graham published a theoretical article focusing on the "fuzzy" (p. 60) boundaries of the constructs and refining the construct definitions using a conceptual analysis. Cox and Graham (2009) gave us their new detailed definitions for each construct. They imagine that Mishra and Koehler's (2006) "new technologies" (p. 1023) would be better defined as "emerging technologies" (Cox & Graham, 2009, p. 63). Cox and Graham (2009) argued that this can help differentiate the technology constructs from the PCK construct, which already includes common technologies (Shulman, 1987; Mishra & Koehler, 2006). In redefining "technology" as "emerging technology," Cox and Graham (2009) suggest that this will allow the definition of "technology" to shift over time, preventing the TPACK model and theory from becoming outdated.

Graham came back to the "fuzzy" (Cox & Graham, 2009, p. 60) boundary issue again in 2011. Graham again called for researchers to be clear about "transparent technologies," or ones we use all the time, versus "emerging technologies" (2011, p. 1956). By defining "emerging technologies" as "new technologies (typically digital technologies) that are being investigated or introduced into a learning environment" (2011, p. 1956), Graham believed that instrumentation research would benefit from better defined constructs with more successful factor analyses. For those interested in a more thorough discussion of TPACK theory, the authors recommend Mishra and Koehler (2006), Scott (2018), or Harris et al. (2017).

Brief Literature Review

Chickering and Gamson (1987) gave us seven principles for undergraduate education, all of which we would recognize under the banner of high-quality learner-centered practices. In 1996, Chickering and Ehrmann added the technology piece calling it a "lever" for student learning (p. 3). While most TPACK do not focus on faculty TPACK attainment or measurement and student learning outcomes (Harris et al., 2017), there have been several just prior to and during the COVID-19 pandemic (e.g., Alshehri, 2020; Brinkley-Etzkorn, 2018; Farrelly & Kaplin, 2019; Fuchs & Tsaganea, 2020; Novita et al., 2022; Oncu, 2021). These studies all point in one direction: student-centered pedagogies and technology-infused instruction based on sound pedagogical practice have positive impacts on student learning.

More than 70 different survey instruments to assess faculty TPACK have been studied and published since 2006 with most of them using a sample of pre-service or in-service K-12 teachers (Scott, 2018, 2020, 2021; Scott & Nimon, 2021). In 2021, Scott conducted an exhaustive review of the TPACK survey instrumentation and published her data set. Scott's data set (2020) allows researchers to search and filter for a variety of factors, including variables studied, specific technologies (if used), the decent line of each instrument, and information on the survey items and population. This data set helps researchers narrow their literature review for the scope of their study along with data reported for those studies, such as this one.

Koehler and Mishra (2005) published a study that included the first introduction to the new TPACK theory. They used a course-specific survey to measure students' developing TPACK. While this instrument found some interesting effects in the learning-by-design process, it did not measure the seven constructs of TPACK as we know it now.

Archambault and Crippen (2009) created a TPACK survey that was designed to allow faculty to self-assess all seven TPACK constructs. They had a large same of U.S. K-12 online faculty participate in this study. The data showed that these faculty felt most comfortable in their knowledge of their teaching content and of pedagogical practices, and less confident of their technology knowledge. This study only reported means and correlations, it did not conduct a factor analysis.

Most self-assessment instruments descend from the Schmidt et al. (2009) instrument (Scott, 2020, 2021). It has been extremely influential by virtue of being "first" to declare a factor structure, although there are issues with their statistical methods (Schmidt et al., 2009; Scott, 2018, 2020, 2021; Scott & Nimon, 2021). Despite issues and the warning to use newer instrumentation by Scott (2021), most survey instruments are still direct descendants of Schmidt et al. (2009).

The most successful thread of self-assessment instrumentation of TPACK in faculty has been published by Chai, Koh, and Tsai (Scott, 2020, 2021). During the period of 2010 – 2019 this group of researchers published 15 papers on TPACK (Scott, 2020, 2021). Over several years this research group relentlessly pursued a solid seven factor structure in a variety of situations. Chai et al. (2010) begins with a student using just the basic TPACK factors (CK, PK, TK, and TPACK) using a pre- and post-test study design with a large sample of Singaporean pre-service teachers. They conducted an EFA which successfully extracted the examined factors. Other notable studies from this group include Chai, Koh, and Tsai (2011) when this team was first able to extract a seven-factor solution. In Koh, Chai, & Tsai (2013), this team successfully extracted all seven factors and conducted an SEM analysis using a sample of pre-service and in-service Singaporean teachers. The follow-up study conducted by Koh and Chai (2014) refines the Koh, Chai, and Tsai (2013) instrument, which successfully extracted all seven factors and conducted a CFA, among other analyses. A detailed analysis of the Chai, Koh, and Tsai research can be found in Scott (2020, 2021).

In 2011 Sahin developed a non-discipline specific TPACK survey which he used in a sample of Turkish pre-service teachers. This study successfully extracted seven factors in his EFA. Celik et al. (2015) used the same instrument for an SEM study with an *a priori* factor structure. Bulut and Isiksal-Bostan (2019) also reported achieving a seven-factor structure using the Sahin (2011) instrument. Most TPACK instruments proport to measure the seven-factor structure of TPACK as theorized by Mishra and Koehler (2006); however, there are some other conceptualizations of TPACK. The two most important are that of Yurdakul et al. (2012) and Yeh et al. (2014).

There are only a handful of studies (*N*=12) that use a sample of two-year public college faculty or junior college faculty using a TPACK survey designed to measure TPACK as Mishra and Koehler (2006) envisioned it. Of those, only seven use a survey designed to measure all seven factors of TPACK (Scott, 2020, 2021). Of those seven, only five performed a factor analysis and only two extracted all seven factors: Koh, Chai, and Tsai (2013) and Scott and Nimon (2021).

Purpose of the Study

The purpose of the current study is to continue to test the construct validity of data from an updated self-report TPACK in 2-year public college faculty:

1. Do the current survey items accurately measure their expected TPACK constructs?
2. Does the current survey provide reliable and valid data when used in a sample U.S. 2-year public college faculty?

METHODS AND MATERIALS

This study uses survey-based methodologies using a 43-item scale derived from Koh, Chai, and Tsai (2014), the refinement of the Koh, Chai, and Tsai (2013) instrument tested with a sample that included junior college faculty, and Scott and Nimon (2021), whose sample was Texas two-year public college faculty.

Instrumentation

Scott & Nimon (2021) published a study of the Community College TPACK Survey for Meaningful Learning (CC-TSML) derived from Koh, Chai, and Tsai (2014), after an exhaustive search for the most reliable and valid instrument in the current literature (Scott, 2021). A subsequent unpublished study by Scott (2021) explored a mixture of items from Scott and Nimon (2021) and Sahin (2011). The exploratory factor analysis found that U.S. community college faculty had a difficult time distinguishing the technology-based items, as many of them loaded on a single technology factor.

To help U.S. two-year public college faculty distinguish among the technology construct items, we borrowed a strategy from Chai, Koh, and Tsai (2011) of adding item stems to the TPK items "In my specific teaching subject…" and TCK items "In teaching almost any subject…". Some TPK items (TPK 04 and TPK 05) had a stem which read "In teaching almost any subject, I can use my institution's learning management system…" We drafted new technology-based items stems and convened an expert committee to sort and rank technology items. Based on their recommendations, a new version of the Scott & Nimon (2021) instrument was created for use in this study. The new instrument represents the seven TPACK constructs with five CK items, six PCK items, seven PK items, five TCK items, six TK items, seven TPK items, and seven TPACK items.

Sample

A random sample of over 35,000 2-year public college faculty from 12 U.S. states were invited by email to participate in the survey. Invitees were randomly selected, using Microsoft Excel functionality, from a database of approximately 72,000 email addresses collected for every 2-year public college in California, Connecticut, Florida, Georgia, Kentucky, Louisiana, Nevada, New Mexico, North Dakota, Texas, Virginia, and West Virginia. Email addresses were collected using Public Information Act (PIA) Requests to individual institutions. These states were selected as representative institutions from various regions of the United States. These colleges range in size from very small and rural to large and urban. Additionally, these states allow for non-residents to collect faculty email addresses using a PIA request. Some states, such as Mississippi, refused our request for email addresses citing state laws requiring PIA requests to come from state citizens. Researchers chose not to request email addresses in all 50 states so that some state populations would be naïve to future studies. Faculty were sent a total of three emails requesting their participation. A total of 318 responses were available for analysis after data cleaning (table 1). Slightly over half of responses (54.72%) came from full-time faculty with the remainder coming from part-time faculty (45.28%). Females represent 60.69% of the sample. The bulk of responders were Baby Boomers (46.54%) or Generation X (39.31%).

Data Analysis

Data were analyzed using IBM® SPSS and AMOS versions 28. Due to sample size constraints, the full data set was used for both the EFA and CFA. ML estimation and an oblique Promax rotation were used in the EFA process. Factors were identified using the Eigenvalue > 1. Covariances were analyzed using ML estimation during the CFA process used to evaluate model fit using both absolute and local fit indices.

RESULTS

A 7-factor structure was found in the EFA and confirmed in the CFA. Constructs found in this process included the expected CK, PK, TK, PCK, and TPACK elements. TPK and TCK items produced a TCK-TPK and a TPK-LMS construct.

Exploratory Factor Analysis

The fifth iteration of the EFA excluded items CK 03, CK 04, CK 05, and TCK 04 due to low factor loadings while item TPK 03 was excluded due to cross-loading. Sampling adequacy was demonstrated with KMO = .920. Bartlett's Test of Sphericity was statistically significant at $p < .001$. Convergent validity is evidenced by pattern coefficient greater than .5 and no evidence of cross-loading in the pattern and structure matrices (Costello & Osborne, 2005), and all items loading most heavily on their factors (Graham et al., 2003). Cronbach's alpha for all scales was greater than .70 as recommended by Kline (2016). The total variance explained by the 7-factor structure is 70.781% (table 2) and the eigenvalue for the first factor not retained is .816.

Confirmatory Factor Analysis

When a study generates non-normal multivariate data, bootstrapping can be used and data can be compared (Kline, 2016). Our critical ratio equals 87.257, demonstrating non-normality. We used bootstrapping and compared the data. As no statistically significant results between the bootstrapped data and non-bootstrapped data were found, we report non-bootstrapped data here (Kline, 2016).

Table 1. Demographics

	Frequency	Percentage	Cumulative Percent
Gender			
Female	193	60.69%	60.69%
Male	115	36.16%	96.86%
Non-Binary/Third Gender	2	0.63%	97.48%
Prefer Not to Say	8	2.52%	100.00%
Total	318	100.00%	
Race/Ethnicity			
American Indian or Alaska Native	3	0.94%	0.94%
Asian	5	1.57%	2.52%
Black or African American	27	8.49%	11.01%
Hispanic	37	11.64%	22.64%
White	220	69.18%	91.82%
Other	26	8.18%	100.00%
Total	318	100.00%	
Generation			
1928 - 1945	15	4.72%	4.72%
1946 - 1964	148	46.54%	51.26%
1965 - 1980	125	39.31%	90.57%
1981 - 1996	29	9.12%	99.69%
1997 or Later	1	0.31%	100.00%
Total	318	100.00%	
Income			
Less than $50,000	114	35.85%	35.85%
$50,000 - $79,999	98	30.82%	66.67%
$80,000 - $149,999	77	24.21%	90.88%
$150,000 or more	11	3.46%	94.34%
Prefer Not to Say	18	5.66%	100.00%
Total	318	100.00%	
Status			
Full-time, tenured or tenure track	73	22.96%	22.96%
Full-time, non-tenure track	101	31.76%	54.72%
Part-time	144	45.28%	100.00%
Total	318	100.00%	

Model Fit

The model under study is complex and the analyses is being conducted with a large data set. These factors may lead to a model failing the chi-square absolute fit test. The 7-factor model that emerged from our analyses appears to fail the X^2 absolute fit statistic with $p < .001$. However, the model achieved better fit statistics for RMSEA (Hair et al., 2015; Kline, 2016) and SRMR (Kline, 2016). The model

Table 2. Internal reliability and variance explained by subscales

	TPACK	PCK	PK	TCK-TPK	TK	CK	TPK-LMS
Cronbach's Alpha	.936	.936	.901	.882	.841	.849	.901
Eigenvalues	12.474	4.836	3.278	2.431	1.635	1.240	1.003
% Var Extracted	32.826	12.726	8.627	6.396	4.303	3.262	2.640
Cumulative Var Extracted	32.826	45.552	54.179	60.575	64.879	68.141	70.781

Note: TPACK=Technological Pedagogical Content Knowledge; PCK=Pedagogical Content Knowledge; PK=Pedagogical Knowledge; TCK-TPK=Technological Content Knowledge-Technological Pedagogical Knowledge; TK=Technological Knowledge; CK=Content Knowledge; TPK-LMS=Technological Pedagogical Knowledge-Learning Management System

demonstrated both absolute (RMSEA and SRMR) and comparative fit (TLI and CFI) signifying that the observed sample data and estimated covariance matrix were equal. Table 3 demonstrates the models absolute fit and local fit statistics.

Reliability and Validity

Each identified subscale was tested by evaluating their pattern and structure coefficients, composite reliability (CR), convergent validity, average variance extracted, and discriminate validity. The CK, PK, TPK-LMS, and TPACK subscales had pattern coefficients > .70 (Kline, 2016) for all items. While TK had three items below the threshold, both TCK-TPK and PCK had one item below .70. All structure coefficients loaded most heavily on their respective factor (Graham et al., 2003). All sub-scales demonstrated CR > .70 (Hair et al., 2015) except for TPK-LMS (CR = .645). Convergent reliability is demonstrated by .95 > pattern coefficients > .70 (Bagozzi & Yi, 1988; Kline, 2016) and AVE > .50 (Bagozzi & Yi, 1988). All subscales demonstrate convergent validity except for TK, TCK-TPK, and PCK due the items with pattern coefficients less than .70. Discriminant validity is measured by the square root of AVE > individual factor correlations (Bagozzi & Yi, 1988; Hair et al., 2015). All subscales show discriminant validity except for PCK (SQRT[AVE]=.922; PCK02 = .933 & PCK03 = .927).

DISCUSSION

The purpose of the study was to answer the following questions:

1. Do the current survey items accurately measure their expected TPACK constructs?
2. Does the current survey provide reliable and valid data when used in a sample U.S. 2-year public college faculty?

We find that most of the items accurately measured their expected TPACK construct by meeting the statistical tests described in the *Results* section and explained in more detail below. However, TCK, and TPK items failed to break into their expected factors. Instead, they created two factors: one comprised of everything except items mentioning the learning management system (LMS; TCK-TPK)

Table 3. CFA model fit indices for the 7-factor correlated model

	X^2	*df*	*p*	X^2/df	TLI	CFI	RMSEA	RMSEA	RMSEA	SRMR
Model					≥ .90	≥ .90	≤ .06	LO	HI	≤ .05
7-Factor Correlated	1276.45	644	<.001	1.982	.920	.927	.056	.056	.060	.048

and those items mentioning the LMS (TPK-LMS). A 7-factor correlated structure was found but was not exactly the expected model. See Tables 3 and 4.

The present researchers found that the study is reliable and valid. Please see Table 5. If the current researchers had eliminated item PCK 06 in the CFA, all validity and reliability measures would have been met. The current researchers decided to leave the item in for reasons explained later in this section.

The EFA showed some issues with CK items that may be related to the pandemic context, while TCK and TPK items demonstrated entanglement. The fifth EFA provided a 7-factor structure. In CFA, all items met the pattern and structure tests, as well as those for composite reliability and convergent validity. One scale had a minor discriminant validity issue that might have been solved with the removal of one item, which the present researchers decided to leave in for reasons explained in the *Confirmatory Factor Analysis* section under *Reliability and Validity*.

Exploratory Factor Analysis

Due to sample size constraints, the total sample ($N = 318$) was used for both EFA and CFA analyses. The sample was shown to be both adequate and sufficiently correlated. The Costello and Osborne (2005) of .5 for pattern coefficients was used as the threshold for determining if an item had a low factor loading and .32 for cross-loading evaluation. After the EFA 1, TPK03 was removed due to cross-loading. EFA 2 found TCK04 cross-loading, so it was removed from further analyses. After the third iteration (EFA 3), we were prompted to removed item CK05 due to low factor loadings; items CK03 and CK04 also exhibited low factor loadings in this iteration. After EFA 4, we removed both CK03 and CK04 due their poor reflection of the construct. EFA 5 produced a 7-factor structure based on Eigenvalue > 1.0.

The 7-factor structure found the expected factors of CK, PK, TK, PCK, and TPACK. The TCK and TPK times loaded on two factors. Most items loaded on a factor we called TCK-TPK with two items which both mention a LMS loading on a separate factor we have called TPK-LMS. See Table 6 for all retained items and their pattern coefficients. Differentiation among technology-based items in U.S. 2-year public college faculty has been an ongoing issue (Scott, 2018; Scott & Nimon, 2021; Scott, 2021). The present study continues the trend; however, it indicates a possible path forward by focusing on LMS items as the focus for the TPK construct in U.S. 2-year public college faculty.

Of the five CK items, only two showed statistical and practical significance. Items that were removed included questions about developing a deeper understanding of their teaching subject, recognizing key leaders in their fields, and attending conferences or activities. All items did well in

Table 4. Implied factor correlations, AVE, and composite reliability

Subscale	TPACK	PCK	PK	TCK-TPK	TK	CK	TPK-LMS
TPACK	***.131***						
PCK	.375	***.922***					
PK	.739	.234	***.868***				
TCK-TPK	.438	.098	.531	***.935***			
TK	.126	.020	.443	.633	***.841***		
CK	.582	.148	.388	.159	.323	***.928***	
TPK-LMS	.582	.073	.373	.712	.547	.173	***.954***
CR	.964	.941	.915	.859	.877	.853	.645
AVE	.824	.850	.753	.874	.708	.862	.910

Note: Square root of AVE on diagonal. All correlations $p < .001$. TPACK=Technological Pedagogical Content Knowledge; PCK=Pedagogical Content Knowledge; PK=Pedagogical Knowledge; TCK-TPK=Technological Content Knowledge-Technological Pedagogical Knowledge; TK=Technological Knowledge; CK=Content Knowledge; TPK-LMS=Technological Pedagogical Knowledge-Learning Management System

Table 5. Composite reliability, convergent validity, and discriminate validity for sub-scales

Sub-Scale	Composite Reliability	Convergent Validity	Discriminant Validity
CK	Yes	Yes	Yes
PK	Yes	Yes	Yes
TK	Yes	Yes	Yes
PCK	Yes	Yes	Partial
TCK-TPK	Yes	Yes	Yes
TPK-LMS	Yes	Yes	Yes
TPACK	Yes	Yes	Yes

Note: TPACK=Technological Pedagogical Content Knowledge; PCK=Pedagogical Content Knowledge; PK=Pedagogical Knowledge; TCK-TPK=Technological Content Knowledge-Technological Pedagogical Knowledge; TK=Technological Knowledge; CK=Content Knowledge; TPK-LMS=Technological Pedagogical Knowledge-Learning Management System

Koh, Chai, and Tsai (2014); however, none of them reached thresholds in this study. These items may not resonate with U.S. community college faculty when this data was collected during the pandemic. Slowing enrollment and budgetary constraints may have also led to these items underperforming when compared to Koh, Chai, and Tsai (2014) or even Scott's (2021) data. These items should be used judiciously in future research with the understanding that they may not perform well, or they might need revision to better reflect teaching realities post-pandemic.

Confirmatory Factor Analysis

Pattern and structure coefficients, discriminant validity, convergent validity, composite reliability, and global fit indices were used to evaluate the CFA. When the results of these tests are combined, we can evaluate how well the data fit the model generated by theory.

Model Fit

We compared our data to RMSEA and SRMR, absolute fit indices, as well as TLI and CFI, which are both comparative fit indices (Schumacker & Lomax, 2016). Fit indices for the 7-factor correlated model ($X^2 = 1276.45$, $df = 644$, $p < .001$) are shown in Table 3. Using thresholds from Schumacker and Lomax (2016) for absolute fit and Hair et al. (2015) thresholds for comparative fit in complex models with large sample sizes, our model demonstrates good model fit, indicating the data fit the model well. Model fit could be improved by ensuring all items have a factor loading > .7 and by using either TPK or TPK-LMS items, but not using them together.

Reliability and Validity

Pattern and structure coefficients typically met the thresholds set by Hair et al. (2015), with exceptions as follows: TK 04 (.637), TK 05 (.587), TK 06 (.685), PCK 06 (.672), and TPK 01 (aka TCK-TPK-TPK01 = .650). All items loaded most heavily on their factor. While some of these items are weak indicators of their construct in this sample, they are both practically and statistically significant (Hair et al., 2015).

TK 04, TK 05, and TK 06 all ask questions about using productivity software such as a word processor, spreadsheet, and cloud-based storage (see Table 6 for items). These items were tested by Koh, Chai, and Tsai (2014) in the study by Scott (2021), as well as in this study. These items were not included in Scott & Nimon (2021). Item TK 04 was flat between Koh, Chai, and Tsai (2014) and the 2021 data, but took a substantial dive in 2022. The item stem "In my day-to-day activities…" was added between the 2021 and 2022 study. This data indicates that stem should be removed from these items before future studies are conducted.

Table 6. Pattern coefficients for items retained and factors observed

	Item	Factor Loading
CK		
CK01	I have sufficient knowledge in my teaching subject.	.862
CK02	I can think about my teaching subject like a subject matter expert.	.862
PK		
PK01	In my general teaching practices, I can stretch my students' thinking by creating challenging tasks for them.	.724
PK02	In my general teaching practices, I can use different assessment methods and techniques.	.772
PK03	In my general teaching practices, I can guide my students in adopting appropriate learning strategies.	.776
PK04	In my general teaching practices, I am aware of possible learning difficulties and misconceptions my students may have.	.738
PK05	In my general teaching practices, I can help my students monitor their own learning.	.740
PK0	In my general teaching practices, I can apply different learning theories and approaches.	.787
PK07	In my general teaching practices, I can help my students reflect on their learning strategies.	.733
TK		
TK01	In my day-to-day activities, I can solve technical problems with my computer.	.751
TK02	In my day-to-day activities, I know and understand basic computer hardware and its function.	.753
TK03	In my day-to-day activities, I am able to use online communication tools.	.832
TK04	In my day-to-day activities, I can use a word processor (e.g., MS Word).	.637
TK05	In my day-to-day activities, I can use a spreadsheet (e.g., MS Excel).	.587
TK06	In my day-to-day activities, I can use cloud-based storage (e.g., Google Drive, OneDrive, DropBox).	.685
PCK		
PCK01	Without using technology, I can address the common misconceptions students have about my teaching subject.	.866
PCK02	Without using technology, I can select effective teaching approaches to guide student thinking and learning in my teaching subject.	.933
PCK03	Without using technology, I can help my students understand the content of my teaching subject using various ways.	.927
PCK04	Without using technology, I can make connections among related topics in my teaching subject.	.910
PCK05	Without using technology, I can meet student learning objectives for courses in my teaching subject.	.790
PCK06	Without using technology, I can develop student assessments (e.g., quizzes, tests) in my teaching subject.	.672

continued on following page

Table 6. Continued

	Item	Factor Loading
TCK-TPK		
TCK-TPK-TCK01	In my specific teaching subject, I can use technology to introduce my students to real-world scenarios.	.726
TCK-TPK-TCK02	In my specific teaching subject, I can evaluate the appropriateness of a new technology for teaching and learning.	.748
TCK-TPK-TCK03	In my specific teaching subject, I can use appropriate technologies (e.g., multimedia resources, simulations) to represent the content.	.801
TCK-TPK-TCK05	In my specific teaching subject, I can develop class activities and projects involving the use of instructional technologies.	.813
TCK-TPK-TPK01	In teaching almost any subject, I can communicate using video-based internet tools (e.g., Zoom, WebEx, FlipGrid, video conferencing).	.650
TCK-TPK-TPK02	In teaching almost any subject, I can help my students use technology to find more information on their own.	.777
TCK-TPK-TPK06	In teaching almost any subject, I can use a variety of web-based technologies to support my teaching and learning activities.	.839
TCK-TPK-TPK07	In teaching almost any subject, I can help my students collaborate with each other using technology.	.762
TCK-LMS		
TCK-LMS-TPK04	In teaching almost any subject, I can use my institution's learning management system to create and deliver quizzes and exams.	.875
TCK-LMS-TPK05	In teaching almost any subject, I can use my institution's learning management system to create, deliver, and assess student assignments.	.945
TPACK		
TPACK01	I can formulate in-depth discussion topics about the content of my teaching subject and facilitate students' online collaboration with appropriate tools.	.778
TPACK02	I can design authentic problems about the content of my teaching subject and represent them using digital technology to engage my students.	.837
TPACK03	I can integrate appropriate instructional methods and digital technologies into my teaching subject.	.863
TPACK04	I can structure activities to help student construct different representations of content in my teaching subject using appropriate technology tools.	.827
TPACK05	I can create self-directed learning activities in the content of my teaching subject with appropriate digital technology tools.	.820
TPACK06	I can design inquiry-based activities to guide students in making sense of the content of my teaching subject using appropriate digital technology tools (e.g., simulations, web-based materials).	.807
TPACK07	I can teach the content of my teaching subject with different instructional strategies, computer applications, and instructional web-based tools.	.839

Note: TPACK=Technological Pedagogical Content Knowledge; PCK=Pedagogical Content Knowledge; PK=Pedagogical Knowledge; TCK-TPK=Technological Content Knowledge-Technological Pedagogical Knowledge; TK=Technological Knowledge; CK=Content Knowledge; TPK-LMS=Technological Pedagogical Knowledge-Learning Management Systm

All PCK items use the stem "Without using technology…" which was present in the Koh, Chai, and Tsai (2014) study. Item PCK 06 asks about developing student assessments. It performed well in the Koh, Chai, and Tsai (2014) study with a pattern coefficient of .815. It performed at the same level in the Scott (2021) study. However, in the present data set it sinks to .672. This suggests that technology has become so ubiquitous in developing student assessments that many faculty cannot imagine trying to create them without using a technology tool. This item may be included in future studies to see if the downward trend continues, indicating that this item may need to be removed, as predicted by Graham (2011).

The TCK and TPK items found themselves intertwined despite the current researchers' efforts to distinguish them by using item stems. The inclusion of the LMS for items TPK 04 and TPK 05 allowed them to break into their own factor. The other items that survived the EFA loaded together on a factor we are calling TCK-TPK, as the TCK items form the bulk of the factor. Item TPK 01 is known as item TCK-TPK-TPK01 in Table 6 to show its current factor and its original location. The item uses its construct stem "In teaching almost any subject…" and asks about video-based internet tools such as Zoom or other video conferencing apps. This item was piloted in Scott (2021) but removed from analysis due to low factor loading. It was included in this study as the original data was collected as worldwide faculty had to become more proficient with these types of technology tools and we expected the item to perform better, which it did with a factor loading of .650. This item should be included in future research to determine if this is the upward trend the present researchers expect.

The sub-scales were also evaluated for discriminate and convergent validity, and composite reliability. See Table 5 for a summary of results. All sub-scales except the PCK sub-scale met composite reliability and convergent validity thresholds indicating that the sub-scales show internal reliability (Kline, 2016) and that the items are closely associated with their factor (Hair et al., 2015). Discriminant validity indicates whether this factor, as measured by the items in the sub-scale, is distinct from other factors. We show this as partial validity in Table 5. If we had chosen to remove item PCK 06, we would have found discriminant validity in the sub-scale. We chose to leave it in and report it so future researchers can compare data on this item in other studies. The current researchers expect to see that item continue to falter without an item revision. Please see Table 6 for all retained items, their pattern coefficients, and their observed factor.

The current instrument returns both valid and reliable data in a population of U.S. two-year public college faculty. A more perfect version may be found with additional work on TK-based items and a re-evaluation of CK items for our current times. Future researchers are encouraged to test this instrument in other populations such as non-U.S. two-year public college faculty and refine items to suit individual contexts.

Limitations

The data were collected during the COVID-19 pandemic using a self-report instrument (potentially inaccurate; Podsakoff et al., 2003). Self-report instruments are a good measure; however, a more holistic approach with faculty self-assessment, student assessment of faculty TPACK, and student achievement data would provide a more robust design and potentially richer data. Studies that could correlate the assessments and student achievement will help bolster our arguments. There is little research that does this (Harris et al., 2017) and we agree that this research is needed. We hope our instrument can help get us there within the 2-year public college zone.

We invited U.S. 2-year public college faculty by email message using email address lists supplied by their home institutions (list accuracy leading to exclusion of eligible faculty), and an increase in non-response bias (Lineback & Thompson, 2010). It is impossible to know how many emails were delivered to faculty inboxes rather than Junk or Spam folders, or simply screened by the institutions. Current trends in efforts to combat phishing and malware likely impact the number of faculty who saw our email invitations.

IMPLICATIONS

While some items may be better predictors of faculty self-assessed KSAs than others, the instrument is suitable for use with U.S. two-year public college faculty. Many items have been tested through Koh, Chai, and Tsai (2014), Scott & Nimon (2021), and Scott (2021). Items that performed poorly were either removed in EFA or are shown here with low factor loadings. Practitioners should be wary of items with low factor loadings as they may not perform well.

TPACK researchers can use the data from this article, data on items from Scott and Nimon (2021), and Koh, Chai, and Tsai (2014), as well as the extensive evaluation of assessment options from Scott (2020, 2021), to discover which items have been tested and in which populations. This may help identify gaps in the research related to instrumentation research. The current researchers would very much like to see an evaluation of the items across Koh, Chai, and Tsai (2014), Scott and Nimon (2021), Scott (2021), this study, and a future study using well-performing or marginal items. A study such as that will help advance the cause of finding an even better instrument to measure TPACK KSAs in U.S. community college faculty.

The entanglement of the TCK and TPK items in this study may have developed due to the addition of the LMS items that broke into a separate factor. We recommend that future researchers test a TPK scale without LMS items as well as a version that only has TPK-LMS items. This might help researchers determine how the various TCK, TPK, and TPK-LMS impact the reliability and validity of an instrument, and which items might resonate best with 2-year public college faculty.

Higher education faculty and leaders could consider using this instrument to evaluate person-job fit of faculty in their attainment KSAs related to TPACK competencies needed to assist at-risk students in their journey to become graduates. While these factors differ slightly from the theoretical model, understanding *how* they differ (entanglement of TK items, primarily) in itself helps identify potential professional development opportunities for job incumbents. We hope this data will be beneficial to individual faculty, departments, schools, and colleges as they attempt to compete in the post-COVID world.

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