A Review of Faculty Self-Assessment TPACK Instruments (January 2006 – March 2020)

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ABSTRACT

Since Mishra and Koehler released their framework of technological pedagogical content knowledge (TPACK), researchers have been attempting to measure it with a variety of self-assessment instruments. Early TPACK instruments struggled with construct validity. More recently, several instruments have been tested for validity and reliability successfully. Since 2006, 233 articles have been published that use a TPACK self-assessment survey of faculty in either a mixed method or empirical study. When faced with this abundance of literature, researchers may be overwhelmed when attempting to find a survey instrument suitable for their own studies. This review is designed to help researchers find valid and reliable instruments for their study by describing frequently used scales, an analysis of respondents from the identified studies, and reliability and validity studies associated with published instruments. A link to the entire data set Technological Pedagogical Content Knowledge (TPACK) Self-Assessment Survey Dataset (2006 – March 2020) is also provided.

KEYWORDS

CFA, Data Set, EFA, Literature Review, Survey, Technological Pedagogical Content Knowledge, Technological Pedagogical Content Knowledge Survey, Validity and Reliability

INTRODUCTION

In 2006, Mishra and Koehler published the technological pedagogical content knowledge (TPACK) framework that postulates seven constructs of teacher expertise necessary for effective teaching. Since 2006, numerous survey instruments to measure TPACK have been developed. Some instruments have been tested for validity and reliability with exploratory factor analysis (EFA) or confirmatory factor analysis (CFA). For many researchers seeking a measure of faculty TPACK for their own study, the number of research articles and plethora of instruments makes it difficult to determine which survey may be best for their research. While other authors have provided analyses of TPACK surveys or literature reviews (e.g., Voogt, Fisser, Pareja Roblin, Tondeur, & van Braak, 2013), the number of research studies and instruments published in the succeeding years suggest a need for an updated analysis. This study aims to fill that gap with a review of survey instruments available in the literature (January 2006 – March 2020).

Figure 1. TPACK framework (© 2012, tpack.org, Used with permission)
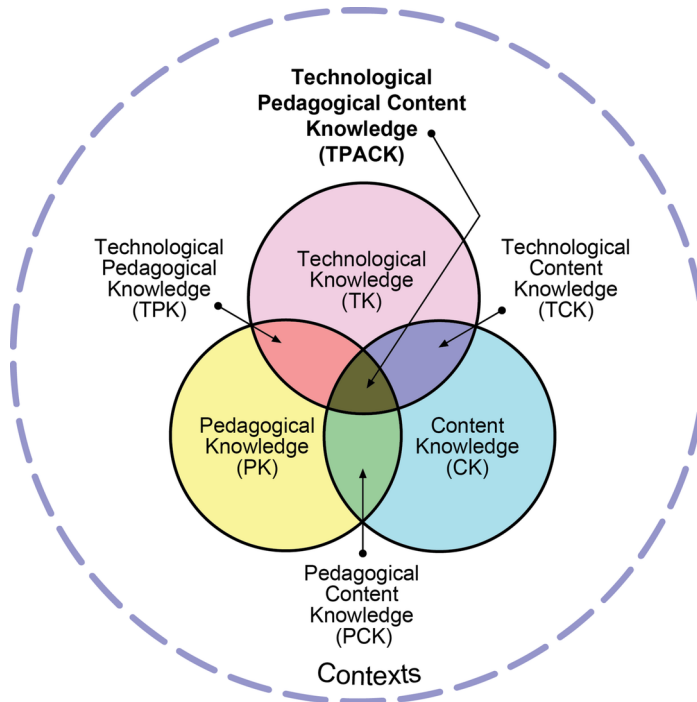
BACKGROUND

Mishra and Koehler's (2006) TPACK framework extended ideas from Shulman's (1987) concept of a new knowledge that is created at the intersection of content knowledge (CK) and pedagogical knowledge (PK) combined with a reconception of Pierson's (2001) notion of TPCK. Unlike Shulman, who only considered "commonplace" technologies (Mishra & Koehler, 2006, p. 1023), they included "digital computers and computer software, artifacts and mechanisms that are new and not yet part of the mainstream" (p. 1023). Mishra and Koehler build on three basic constructs: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), unlike Pierson (2001). Mishra and Koehler accepted Shulman's (1987) theory that PCK develops from CK and PK 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 within a larger disciplinary context (see Figure 1).

Cox and Graham (2009) attempted to describe the TPACK constructs to further define the boundaries of the factors, clarifying what is and is not part of each construct. They provided elaborated definitions for each construct, giving specific examples for each. The redefinition of technology across the technology dimensions to "emerging technologies" (p.63) instead of the "new" technologies suggested by Mishra and Koehler (2006). Cox and Graham did not limit their definition of technology to information and communication technologies (ICT), allowing the definition to change over time and preventing the TPACK framework from becoming obsolete. This conception of technology suggests that measurement instruments will need to evolve as some technologies become common, others die, and more emerge (Cox & Graham, 2009).

Angeli and Valanides (2009) suggested that for TPACK theory to be different from PCK theory (Shulman, 1987), it should concentrate on ICT coupled with TPACK (ICT–TPACK). They proposed

a focus on the three base constructs of Mishra and Koehler (2006): CK, PK, and TK, along with two additional constructs: "knowledge of students and knowledge of the context in which the learning takes place" (Angeli & Valanides, 2009, p. 158).

Graham (2011) revisited the boundary issues identified by Cox and Graham (2009). Graham repeated the call for researchers to differentiate between "transparent technologies" and "emerging technologies" (2011; p. 1956). He defined emerging technologies as "new technologies (typically digital technologies) that are being investigated or introduced into a learning environment" (Graham, 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).

Yurdakul, Odabasi, Kilicer, Coklar, Birinci, and Kurt (2012) developed a scale to measure TPACK, the central construct of the TPACK framework, through the use of a self-assessment of skill competency using a 5-point Likert scale (e.g., I can easily do/I certainly can't do it). The TPACK-Deep scale consists of four factors: design, exertion, ethics, and proficiency.

Yeh, Hsu, Wu, Hwang, and Lin (2014) suggested a different way to look at TPACK from the practical standpoint of teachers' knowledge and experience. The TPACK-Practical survey uses 5-point Likert anchors of importance in five factors: learners, subject content, curriculum design, practical teaching, and assessment. Sample items include "Know how to use ICT to know more about students" (learners) and "Be able to use ICT to facilitate the achievement of teaching objectives" (practical teaching).

Each of these researchers has contributed to the conceptualization of TPACK. These various approaches to TPACK theory influence measurement instruments. As scholars evaluate existing instruments for possible use, the literature review and an examination of technology-based items may help them determine which theories underpin the specific instruments. Where factors other than the typical seven factors are extracted or hypothesized, researchers can determine if that is an intentional theoretical consideration or a function of failed factor extraction.

Early TPACK Survey Instruments

The earliest TPACK instrument in the literature was created by Koehler and Mishra in 2005. The 2005 study gave a brief introduction to the TPACK framework and its Venn diagram model (see Figure 1). Koehler and Mishra created a course-specific survey designed to measure participant learning and to provide empirical evidence of their theory. They surveyed a small sample of 17 U.S. participants, including both instructors teaching the course and students participating in the course. The 33-item survey used a 7-point Likert scale. While this first effort to measure TPACK found some very large effects in the learning-by-design process, it did not measure the seven TPACK constructs. The next published effort to measure TPACK came from Archambault and Crippen (2006). They used an 11-item TPACK survey in a sample of 34 online K–12 teachers in the U.S. to self-assess preparedness on a 4-point Likert scale in three areas of expertise: online pedagogy, course design, and technical assistance.

In 2009, studies from Archambault and Crippen; Graham, Burgoyne, Cantrell, Smith, St. Clair, and Harris; and Schmidt, Baran, Thompson, Mishra, Koehler, and Shin entered the literature and kick-started the proliferation of measurement instruments. Archambault and Crippen (2009) designed a survey for use in 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). This survey allowed teachers to self-assess items in all seven domains of TPACK with items such as "My ability to adjust teaching methodology based on student performance/feedback". Graham et al. (2009) published the first study focused on a specific discipline (science) but also only measured technology dimensions (TK, TPK, TCK, and TPACK). The 31-item instrument used a 6-point Likert scale (1=not confident at all, 6=completely confident) with items such as "Use digital technologies that allow scientists to create and manipulate models of scientific phenomenon." The Graham et al. instrument was tested in a sample of 15 U.S. in-service elementary and secondary science teachers.

Schmidt et al. (2009) studied the internal reliability and validity of the data gathered with their new 47-item survey designed to measure the seven constructs in a sample of 124 pre-service PK-6 teachers in the U.S. The survey used a 5-point Likert scale (1=strongly disagree, 5=strongly agree) with items such as "I can select technologies to use in my classroom to enhance what I teach, how I teach, and what students learn." They divided the CK items into four content areas in which U.S. elementary teachers should have proficiency: math, science, social studies, and literacy. Schmidt et al. did not have a large enough sample to conduct a traditional factor analysis. Instead, they "investigated the construct validity for each knowledge domain subscale using principle components factor analysis… within each knowledge domain" (Schmidt et al., p. 130).

Early instrument development and empirical studies may have been hampered by the "fuzzy" nature of the TPACK construct boundaries (Cox & Graham, 2009, p. 60; Graham, 2011). Since the TPACK framework was published (Mishra & Koehler, 2006), hundreds of studies have been conducted to explore TPACK in a variety of populations and contexts (Scott, 2018). This proliferation may make it difficult for researchers of faculty TPACK to locate an instrument which may best suit their research needs. Understanding the theoretical underpinning, constructs measured, survey lineage, items, populations in which the instrument has been previously used, and factor analytic reliability and validity studies can help researchers discover an existing survey instrument for their research.

Factor Analytic Studies

Factor analytics studies can help researchers identify instruments that have proven item-to-construct relationships. Exploratory factor analysis (EFA) allows researchers to understand the link between items (observed variables) and constructs (factors; unobserved variables) (e.g., Hair et al., 2013; Thompson, 2004). EFA permits the researcher to explore the data without specifying the number of factors or how items relate to the factors (e.g., Hair et al., 2013; Thompson, 2004). EFA is appropriate when an instrument has never been tested with EFA before, when an instrument with a previously reported EFA is being used with a new population, when items have been changed from an instrument's previously reported form, when new items have been added, or when a combination of reported instruments is used.

By contrast, confirmatory factor analysis (CFA) is used when researchers have "knowledge of the theory, empirical research, or both" (Byrne, 2010, p. 6) and can specify *a priori* the number of factors and how items are related to those factors (e.g., Byrne, 2010; Hair et al., 2013). Researchers can use CFA without an EFA if they are using instruments that have reported quality EFA studies provided the instrument has not been changed in any substantive way and they are using it in a very similar population (e.g., same country, same grade level, same subject).

EFA and CFA analyses are large sample techniques (e.g., Kline, 2016; Thompson, 2004). Sample size can impact the stability of factor loadings, number of replicable factors, and the ability to generalize to the population (e.g., Aleamoni, 1976; Cliff, 1970; Osborne & Costello, 2004). Total sample size (N) and respondent-to-item (RTI) ratio also impact both Type I and Type II errors (e.g., Osborne & Costello, 2004). As a quick method of determining adequacy of sample size in a study, researchers can use both total sample (N) and respondent-to-item (RTI) ratios (e.g., Osborne & Costello, 2004). This information coupled with factor analytical results may help researchers choose an instrument for their study.

Comfrey and Lee (1992) state that "the adequacy of sample size might be evaluated very roughly" as N=100 is poor, N=300 is good, N=500 is very good, and N=1,000+ is excellent (p. 2017). Osborne and Costello (2004) determine that following absolute sample size is overly simplistic. The most often cited "rule of thumb" on RTI comes from Nunnally (1978) who suggested that RTI for factor analytics should be at least 10. Thompson (2004) tells us that the most often recommended RTI is between 10 and 20. Osborne and Costello found that higher RTIs found better outcomes is terms of lower Type I and Type II error. The interplay between N and RTI is important (Costello & Osborne, 2004). In their study, they found of that as N increases, a lower RTI may be acceptable and that as RTI

increases, a lower N may be acceptable. The quality of the validity and reliability study may impact a scholar's decision in choosing a survey for use in their research. Understanding an instrument's previous studies in terms of N, RTI, and type of factor analytics can help researchers differentiate quality reliability and validity studies.

TPACK Literature Review Studies

Several broad reviews of the TPACK literature or instruments have been published since 2010 (e.g., Chai, Koh, & Tsai, 2013; Jaikaran-Doe & Doe, 2015; Voogt et al., 2013) but, over time, some have become dated. More current literature reviews have typically focused on specific issues such as faculty professional development (Moreno, Montoro, & Colon, 2019), faculty professional development within the STEM context (Chai, 2019) or the importance of faculty TPACK in creating effective learning environments within the reading context (Sarjoni, Rahman, Sabil, & Khambari, 2020). Njiku, Mutarutinya, and Maniraho's (2020) study evaluated TPACK survey instruments from 28 peer-reviewed articles. Their study was limited by the databases they used (Google Scholar, ERIC, and Scopus) and singular search phrase, "TPACK survey instrument validation" (Njiku et al., 2020, p. 5). While other authors have conducted literature reviews, the present researcher was unable to find any other peer-reviewed articles that: (1) conducted an exhaustive literature review over this period, (2) focused specifically on faculty self-assessment TPACK instrumentation, and (3) included the entire data set for use by other researchers.

MAIN FOCUS OF THE ARTICLE

In order to help scholars discover a faculty self-assessment TPACK instrument for use in their own studies, this article provides a review of the most influential instruments, a summary survey participant demographics, and a brief overview of the most important reliability and validity studies associated with the most common survey lineages. The accompanying data set, *Technological Pedagogical Content Knowledge (TPACK) Self-Assessment Data Set (January 2006 – March 2020),* gives researchers access to the exhaustive literature review of 233 peer-reviewed research studies as well as additional details for each entry including study type, study purpose, survey discipline, anchors, sample items, and more.
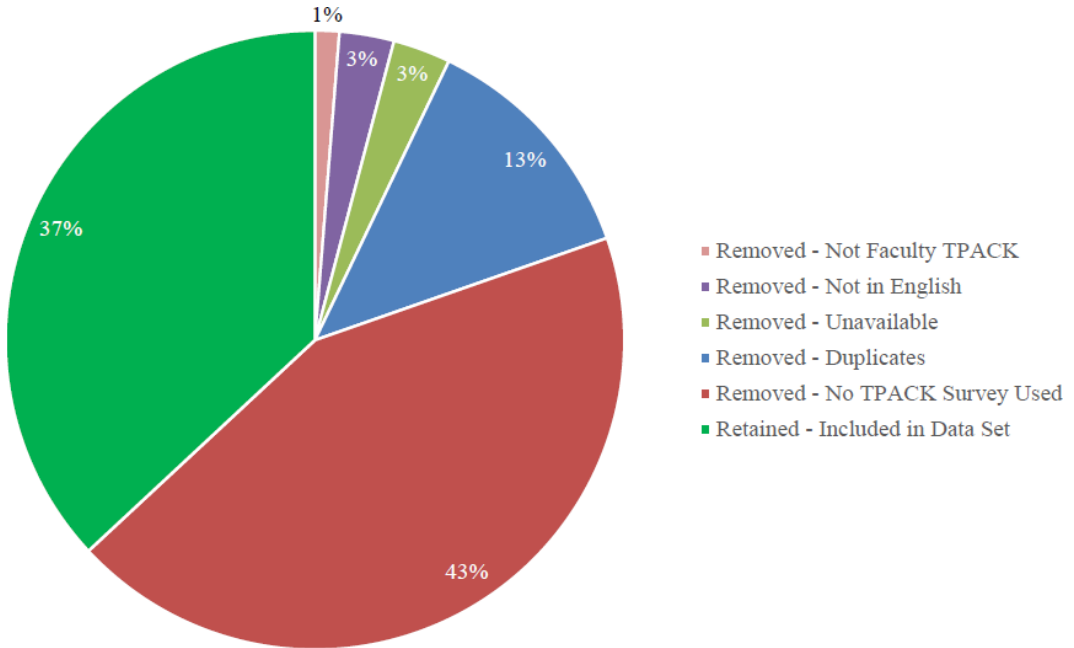
METHODOLOGY

To locate articles with survey instruments designed to measure faculty TPACK, this researcher followed the literature review strategy from Voogt et al. (2013) and a modified PRIMSA process (Moher, Liberati, Tetzlaff, & Altman, 2009). This researcher searched Education Resources Information Center (ERIC), Web of Science, Scopus, and PsycINFO databases between January 2006 – March 2020 for peer-reviewed articles in English using the search terms "technological pedagogical content knowledge," "TPCK," and "TPACK" (Voogt et al., 2013) in the article title. A total of 631 articles were identified. Spreadsheets of the search results were combined and duplicates eliminated, leaving a total of 552 unique articles.

Abstracts of all 552 articles were screened and an initial classification was made (e.g., empirical, theoretical). Copies of articles were downloaded. Of the 552 articles identified, 19 items were excluded as they were unavailable from libraries, interlibrary loan, or online; 18 articles were excluded as not available in English; and 274 were excluded as no TPACK survey instrumentation was used. A TPACK survey was defined as any instrument the original study identified as a TPACK survey. A further eight studies were excluded from consideration based on study type or respondent type, leaving 233 articles available for the analysis (Figure 2).

Each of the 233 articles was coded to study type and survey lineage, (i.e., from which previous survey was it derived, if any). Study type was determined by reading methodology sections to evaluate

Figure 2. Percentage of articles removed and retained during the PRISMA process (N=631)

whether a strictly quantitative approach to the survey data was used or if a mixed methods methodology was used that included a TPACK survey. The author reviewed quantitative analysis types used with a focus on reliability and validity studies, how many factors were extracted, N, number of items in the survey, RTI, location of the survey population, status of sample population, teaching level, respondent discipline, and respondent type. The researcher also included columns for sample items and important notes about the study (e.g., item stems, translations). The reliability of coding was enhanced by an iterative process with temporal separations as the coding was checked and revised, as necessary, multiple times over a 20-month period. The complete data set, *Technological Pedagogical Content Knowledge (TPACK) Self-Assessment Data Set (January 2006 – March 2020),* is available for use by researchers with proper attribution and citation. See the Data Set section at the end of this article for the link (Figure 3).

DATA ANALYSIS

An analysis of study instrument lineage was undertaken to determine which surveys were most used in the literature. Some articles were grouped together based on research team to determine their true impact on the literature (see Table 1). An evaluation of study participants was done based on status, level, teaching discipline, and location (see Table 2). Factor analytic studies are an important way to determine the validity and reliability of an instrument in a population (e.g, Kline, 2016; Thompson, 2004) so an analysis by study type and survey lineage was conducted (N=89). Please see the Data Set for additional details on each study, its survey lineage, sample, N, RTI, and more information.

Study Instrument Lineage

To determine the influence of various instruments in the literature, each article was reviewed to determine the background of its instrument. Studies with new survey instruments were coded to their own authors. Studies that used a translation of an instrument without changing it are coded to the

Figure 3. Number of peer-reviewed articles included by publication year (2006 – 2020) (N=233)
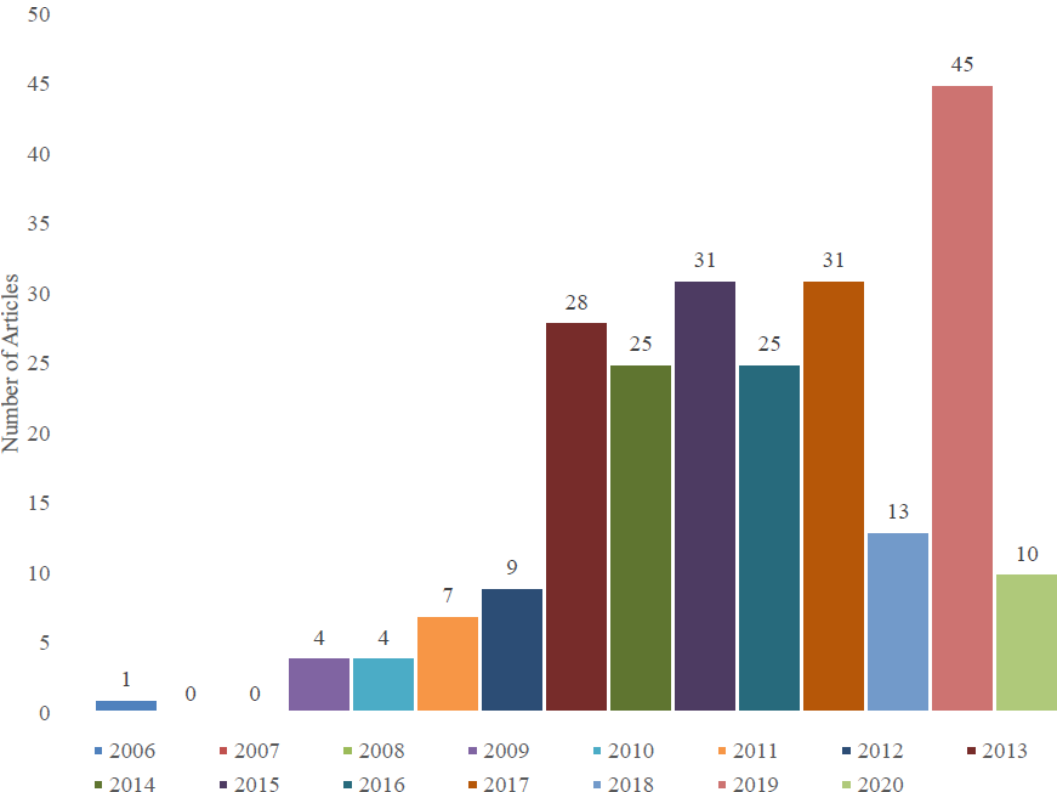
original authors. To evaluate the impact of authors or groups of authors with multiples studies that may build upon each other, studies were coded in groups, as appropriate. These groups of studies were counted, and a percentage of the literature was calculated. To evaluate the total impact of these studies on the literature, a running total of articles and percentages were calculated (see Table 1).

The survey instrument by Schmidt et al. (2009) accounts for 27.0% of articles, more than any other instrument. This 47-item survey is pedagogical agnostic and asks only general technology questions. The factor analysis found the expected seven factors of Mishra and Koehler (2006); however, the EFA was conducted on each sub-scale independently.

When one accounts for the group of studies conducted by authors Chai, Koh, and others their true influence on the literature is more apparent (12.9%, See Table 1). This group of authors frequently writes together and articles may list either Chai or Koh as first author and may include other authors (e.g., Koh, Chai, & Lim, 2016;). Their body of work has focused on refining an instrument to measure TPACK with a focus on constructivist pedagogies and emerging technologies.

The Sahin (2011) survey accounts for 8.2% of the literature. It consists of 47 items with a 5-point Likert scale. Its TK items use common technologies, is pedagogically agnostic, and is designed to be used in any discipline context.

The Yurdakul et al. (2012) survey accounts for 8.2% of the reported literature. This 33-item instrument was designed to measure TPACK as a whole entity through competency areas using a 5-point Likert scale (I can easily do/I certainly can't do it). It is not designed to measure the seven factors of TPACK. The factor analysis found four factors: design, exertion, ethics, and proficiency. Only sample items are included in this article, so it was not possible to determine if a specific pedagogy was stressed; however, innovative technologies are emphasized.

Table 1. Survey instrument impact on the literature

Survey Lineage	Individual Articles		Total Articles N = 233)	
	# of Articles	% of Articles	# of Articles	% of Articles
Schmidt et al., 2009	63	27.0%	63	27.0%
Chai, Koh, et al.[a], 2010 - 2019	30	12.9%	93	39.9%
Sahin, 2011	19	8.2%	112	48.1%
Yurdakul et al., 2012	19	8.2%	131	56.2%
Archambault et al.[b], 2006 - 2011	11	4.7%	142	60.9%
Yeh et al.[c], 2013 - 2017	7	3.0%	149	63.9%
Graham et al., 2009	6	2.6%	155	66.5%
Jang & Tsai, 2012 - 2013	6	2.6%	161	69.1%
Jamieson Proctor et al.[d], 2010 - 2013	5	2.1%	166	71.2%
Baser et al., 2016	4	1.7%	170	73.0%
Bilici et al., 2013	4	1.7%	174	74.7%
Fisser et al., 2013	3	1.3%	177	76.0%
Hsu et al., 2013	3	1.3%	180	77.3%
Lee & Tsai, 2008 - 2010	3	1.3%	183	78.5%
Horzum et al., 2014	2	0.9%	185	79.4%
Hosseini & Kamal, 2012	2	0.9%	187	80.3%
Kaya & Dag, 2013	2	0.9%	189	81.1%
Kiray, 2016	2	0.9%	191	82.0%
Lin et al., 2013	2	0.9%	193	82.8%
Lux et al., 2012	2	0.9%	195	83.7%
Rienties, Brouwer et al., 2013	2	0.9%	197	84.5%
Semiz & Ince, 2012	2	0.9%	199	85.4%
Valtonen et al., 2015	2	0.9%	201	86.3%
Zelkowski et al., 2013	2	0.9%	203	87.1%
Total	203	87.1%		

a=author group publishes in a variety of orders and may include additional authors;
b=author publishes with a variety of other authors and may not always be listed as first author;
c=author publishes with other authors but is always listed as first author;
d =author publishes with others but may or may not be listed as first author.

Study Participants

About half of the TPACK literature is focused on studying pre-service teachers (50.6%), many of them within the context of courses they are taking in their teacher education. Some studies (6.4%) used both pre-service and in-service teachers (e.g., Hosseini & Kamal, 2013). Both mixed methods and empirical studies focus more heavily on pre-service than in-service teachers, possibly due to the ease of access to study participants. Less than 1.0% of studies do not report teacher status.

A majority (43.8%) of study participants were of an indeterminate level. Of those where a level is reported, most are either early childhood/elementary/primary school (32.6%) or high school/secondary (26.2%) teachers. Some studies report using middle school (10.3%) or higher education

(9.4%) faculty. The difference in reporting grade level in various countries could be skewing these data. A few studies include faculty of more than one level grouping (e.g., Doering, Veletsianos, Scharber, & Miller, 2009; Jang & Tsai, 2013). No totals are provided for this portion of Table 2 for this reason.

Most study participants did not have a reported teaching discipline (43.8%). Of the teaching disciplines reported in mixed methods studies, the majority were either in English (20.0%) or science (15.4%). In empirical research, most studies include multiple disciplines (16.1%). Studies that include multiple disciplines typically included the four subjects from Schmidt et al. (2009): math, science, literacy, and social studies. These were not combined with the separate groups in this analysis and form a portion of the multi-disciplinary category in Table 2. Of those empirical studies reporting a specific discipline, science (11.3%) is the most reported and includes science as a general discipline and as a specific subject (e.g., chemistry, biology).

Mixed methods studies show the largest number coming from Turkey (29.2%) and the U.S. (24.6%). Europe provide data for 7.7% of mixed methods articles reviewed while Africa and Australia account for 6.2% each. The largest number of quantitative studies use participants from Turkey (32.7%), the U.S (11.9%), and Taiwan (10.7%). It is important to note that the participant location in some studies had to be inferred based the researcher's location rather than a specification in the methods section of papers.

Analysis by Survey Lineage

Factor analytic studies help researchers determine which instruments have been proven reliable and valid in their populations. An analysis of EFA and CFA studies (N=86) by survey lineage (see the Data Set) was conducted to help researchers understand the factor analytics studies as well as their successes and failures.

Schmidt et al., 2009

The 47-item survey is are designed to measure the seven TPACK domains on a 5-point Likert scale (1=strongly disagree; 5 = strongly agree). Sample items include "I have sufficient knowledge about mathematics" (CK), "I have the technical skills I need to use technology" (TK), and "I can choose technologies that enhance students' learning for a lesson" (TPK). The instrument is pedagogically agnostic and is basic and generical technologically. Schmidt et al. (2009) used their instrument in an empirical study of 124 pre-service PK-6 teachers in the U.S. The study lacked an adequate N to conduct a traditional factor analysis so Schmidt et al. did the analysis on each sub-scale independently. Given that EFA is designed to provide information on how items relate to constructs (e.g., Byrne, 2010; Hair et al., 2013), it is unlikely that the EFA conducted by Schmidt et al. is statistically reliable. Reported alphas for the sub-scales were as follows: TK ($\alpha = .82$), CK-Math ($\alpha = .85$), CK-Social Studies ($\alpha = .84$), CK-Science ($\alpha = .82$), CK-Literacy ($\alpha = .75$), PK ($\alpha = .84$), PCK ($\alpha= .85$), TCK ($\alpha = .80$), TPK ($\alpha=.86$), TPCK ($\alpha = .92$).

Eight studies use an EFA-only approach using Schmidt et al. (2009) as their starting point. Koh et al. (2010) developed a 27-item generic survey to measure all seven factors in a sample of 1,185 pre-service teachers in Singapore. Despite having an adequate sample (N=1,185, RTI=43.89) to conduct an EFA, they were only able to extract five factors with $\alpha = .83$ - .96 (Koh et al., 2010). This team of researchers has gone on to revise and refine their instrument and has published numerous studies which we will examine in detail in the *Chai, Koh, and Others (2010 – 2019)* section. Of all the EFA-only studies associated with the Schmidt et al. conducted between 2009 and March 2020, the only study that reports extracting all seven expected factors is the Schmidt et al. study itself using a non-standard factorial approach.

Five studies reported using a CFA-only approach when analyzing data from a survey derived from Schmidt et al. (2009). Semiz and Ince (2012) studied 760 pre-service physical education teachers in Turkey using a 19-item version of the scale designed to measure all seven factors (RTI=40.00). Alphas are reported as .77 - .95 for a five-factor solution. Giannakos et al. (2015) conducted a study

Table 2. Study participants' status, teaching level, and location

Studies	Mixed Methods N = 65		Empirical N = 168		Total N = 233	
	# of Articles	% of Articles	# of Articles	% of Articles	# of Articles	% of Articles
Status						
In-service	31	47.7%	67	39.9%	98	42.1%
Pre-service	29	44.6%	89	53.0%	118	50.6%
Pre-service and In-service	4	6.2%	11	6.5%	15	6.4%
Not Reported	1	1.5%	1	0.6%	2	0.9%
Total	65	100.0%	168	100.0%	233	100.0%
Level[a]						
Early Childhood/ Elementary/ Primary	17	26.2%	59	35.1%	76	32.6%
Middle School	10	15.4%	14	8.3%	24	10.3%
High School/Secondary	17	26.2%	44	26.2%	61	26.2%
Higher Education	6	9.2%	16	9.5%	22	9.4%
Not Reported	29	44.6%	73	43.5%	102	43.8%
Discipline						
Education	1	1.5%	4	2.4%	5	2.1%
English	13	20.0%	9	5.4%	22	9.4%
Language	3	4.6%	3	1.8%	6	2.6%
Math	5	7.7%	11	6.5%	16	6.9%
Math and Science	2	3.1%	4	2.4%	6	2.6%
Medicine	0	0.0%	2	1.2%	2	0.9%
Miscellaneous	1	1.5%	7	4.2%	8	3.4%
Multi-disciplinary	6	9.2%	27	16.1%	33	14.2%
Physical Education	0	0.0%	5	3.0%	5	2.1%
Science	10	15.4%	19	11.3%	29	12.4%
Social Science	4	6.2%	2	1.2%	6	2.6%
Special Education	0	0.0%	2	1.2%	2	0.9%
Not reported	20	30.8%	73	43.5%	93	39.9%
Total	65	69.2%	168	56.5%	233	60.1%
Location[b]						
Africa	4	6.2%	2	1.2%	6	2.6%
Australia	4	6.2%	6	3.6%	10	4.3%
China	1	1.5%	11	6.5%	12	5.2%
Columbia	0	0.0%	1	0.6%	1	0.4%
Europe	5	7.7%	15	8.9%	20	8.6%
Malaysia	1	1.5%	4	2.4%	5	2.1%
Middle East	3	4.6%	8	4.8%	11	4.7%
Multi-national	3	4.6%	7	4.2%	10	4.3%

Table 2. Continued

Studies	Mixed Methods N = 65		Empirical N = 168		Total N = 233	
	# of Articles	% of Articles	# of Articles	% of Articles	# of Articles	% of Articles
New Zealand	0	0.0%	1	0.6%	1	0.4%
Singapore	2	3.1%	13	7.7%	15	6.4%
South Asia	1	1.5%	1	0.6%	2	0.9%
Southeast Asia	3	4.6%	6	3.6%	9	3.9%
Taiwan	3	4.6%	18	10.7%	21	9.0%
Turkey	19	29.2%	55	32.7%	74	31.8%
USA	16	24.6%	20	11.9%	36	15.5%
Total	65	100.0%	168	100.0%	233	100.0%

a=totals are greater than the number of studies as some use multiple groups (e.g., elementary and secondary);
b=individual studies come from a variety of countries within a region.

of 636 in-service high school computer science teachers in Greece using a 21-item version of the survey and achieved the 7-factor solution with α = .70 - .84 (RTI=30.29).

Six studies reported a sequential EFA-CFA analysis using a Schmidt et al. (2009) derived survey. Chai, Koh, Tsai, and Tan (2011) used a 46-item generic version of the instrument with 343 pre-service primary teachers in Singapore and were able to extract five factors with α = .86 - .95, RTI=7.46. In 2019, Barisic, Divjak, and Kirinic achieved the 7-factor structure in a study of 337 pre-service early childhood and elementary school teachers in Croatia using a 47-item multi-disciplinary version of the instrument, RTI= 7.17. All sub-scale alphas were approximately .91.

Chai, Koh, and Others (2010 – 2019)

Koh et al., (2010) studied 1,185 pre-service Singaporean teachers using the Schmidt et al. (2009) 27-item instrument (RTI=43.89). The instrument was adapted by altering content-specific questions and changing the scale anchors from a 5-point to a 7-point Likert scale (1=strongly disagree, 7=strongly agree). The EFA was able to extract only five factors which Koh et al. named TK (α=.87), CK (α=.93), Knowledge of Pedagogy (KP, α=.93), Knowledge of Teaching with Technology (KTT, α=.96), Knowledge of Critical Reflections (KCR, α=.83). Some PCK items loaded with PK items creating the KP factor. Items designed to measure TPK, TCK, and TPACK loaded together to create the KTT factor. Left over TPK items loaded together to create the KCR factor.

The Chai et al. (2010) study of 889 pre-service secondary teachers in Taiwan used an instrument derived from Schmidt et al. (2009). The instrument was designed to only measure basic TPACK constructs (TK, PK, CK, and TPACK) using 18 items with CK items measured generically and using a 7-point Likert scale. They conducted a sequential EFA-CFA (RTI=49.39) and successfully extracted the four factors expected with α = .85 - .94 (post-course).

Chai et al., (2011) continued to refine the instrument from Chai et al. (2010). Changes made to the Chai et al. (2010) instrument include adding additional items to measure the intermediate constructs of TPACK (TCK, TPK, PCK) as well as items focused on constructivist pedagogies and technologies. The instrument developed was 36 items; 34 items were retained in the EFA. Eight factors were extracted in the EFA as expected with two CK constructs associated with different teaching subjects. Alphas were reported for each sub-scale (TK=.87, CK-CS1=.84, CK-CS2=.86, PK=.93, PCK=.87, TPK=.90, TCK=.92, TPACK=.94).

This team of researchers continued to use and refine the instrument from Chai et al. (2011) in other studies (see the Data Set). The instrument version of Koh, Chai, and Tsai (2013) was also used

in a study by Koh and Chai (2014). The body of work by this research team has focused on refining an instrument to focus on constructivist pedagogies and innovative technologies. Sample items from Koh, Chai, & Tsai (2014) include: "I am able to use technology to introduce my students to real world scenarios" (TPK) and "I can design authentic problems about the content knowledge and represent them through computers to engage my students" (TPACK). A detailed analysis of how each study changed and refined the instrument can be found in Scott (2018).

Twelve other studies report an EFA-only, a sequential EFA-CFA, or other factor analysis study. Huang, Chen, & Jang (2020) conduced an EFA analysis of the data collected from a sample of 415 in-service Taiwanese special education teachers using a 39-item (RTI=10.64) adaptation of Chai, Koh, and Tsai (2011). They were not able to achieve the expected factor structure and had issues with items loading on unexpected factors (Huang et al., 2020, p. 5-7). Alphas for this instrument are reported as .86 - .96. In 2015, Dong, Chai, Sang, Koh, and Tsai studied a 38-item generic instrument derived from Chai, Ng, Li, Hong, and Koh (2013) in a sample of 784 pre-service and in-service teachers in China, RTI=20.63. They successfully extracted the expected 7-factor solution and α = .88 - .95.

Sahin, 2011

Sahin (2011) developed and tested a 47-item scale designed to measure all seven factors of TPACK using a 5-point Likert scale (1 = not at all, 5=complete). Items use the stem "I have knowledge in…". Sample items include: "Using an electronic spreadsheet program (ex., MS Excel)" (TK) and "Taking a leadership role among my colleagues in the integration of content, pedagogy, and technology knowledge" (TPACK).

The instrument was tested using EFA on the data gathered from 553 pre-service teachers in Turkey (RTI=4.36). TK items were designed to measure knowledge in using a variety of hardware and software, PK items were pedagogically agnostic. CK items were worded generally as "my content area." Cronbach's alpha for each sub-scale is reported as TK=.93, PK=.90, CK=.86, TPK=.88, TCK=.88, PCK=.92, and TPACK=.92.

Two studies by Acikgul and Aslaner (2019a; 2019b) conducted CFA-only analysis using a Sahin-derived instrument measuring content factors (CK, PCK, TCK, and TPACK) in a sample of 88 pre-service elementary math teachers. Acikgul and Aslander (2019a) used a 32-item geometry instrument but did not report alphas. Acikgul and Aslaner (2019b) used a 30-item geometry instrument and α = .89 - .93. In 2019, Bulut and Isiksal-Bostan studied the data from 780 pre-service elementary math teachers in Turkey, RTI=15.29, using a sequential EFA-CFA analysis. They used a 51-item instrument that extracted the expected 7-factor solution with α = .83 - .92. As of March 2020, all factor analytic studies using a Sahin (2011) instrument had successfully extracted the expected 7-factor solution.

Yurdakul et al., 2012

Yurdakul et al. (2012) used their new 33-item instrument to measure the central TPACK construct in total using a 5-point Likert scale (I can easily do/I certainly can't do). Factors associated with this scale include design, exertion, ethics, and proficiency. Sample items include: "To use innovative technologies (Facebook, blogs, twitter, podcasting, etc.) to support the teaching and learning process" (exertion) and "To troubleshoot problems that could be encountered with online educational environments (WebCT, Moodle, etc.)" (proficiency).

Yurdakul et al. (2012) conducted a sequential EFA-CFA analyses on data gathered from 995 pre-service teachers in Turkey. They reported a four-factor solution (RTI=30.15) with α = .85 - .92. In 2015, Arslan conducted a CFA-only analysis of data from a study of 1,028 pre-service physical education teachers in Turkey, RTI=31.15, using a 33-item instrument measuring the four constructs of Yurdakul et al.

DISCUSSION

While there are many studies in the peer-reviewed literature using a TPACK instrument, a few have had a huge impact (See Table 1). Schmidt et al. (2009) or a derivative of it is used in 27.0% of the total literature, an instrument from Chai, Koh, and others (2010 – 2019) is used 12.9% of the time, or a Sahin (2011) instrument is used 8.2% in the literature. For researchers wishing to use a different TPACK model, Yurdakul et al. (2012) captures 8.2% of the literature.

Schmidt et al. (2009) or instruments derived from that survey dominate the literature. When factor analytic studies are examined, many studies have failed to extract the expected 7-factor structure even when using large sample sizes (e.g., Koh et al., 2010). This researcher has not been able to find any studies performed in U.S. elementary school teachers (Schmidt et al., 2009 target population) that has been able to find the 7-factor structure. Giannakos et al. (2015) is the only factor analytic study using a Schmidt et al. based instrument to successfully extract all seven factors of TPACK in a data set with adequate sample size and RTI (e.g., Kline, 2016; Osborne & Costello, 2004; Thompson, 2004). The initial problematic factor analysis may explain why other studies have had trouble extracting the 7-factor solution. Advantages to this instrument include its wide use in the literature, appropriateness for elementary school teachers, and generic view of technology. Disadvantages to this survey include its CK-related constructs consist of a single item customized for the four subject areas measured, its TK-related constructs use very simplistic items, and many failed factor analytic studies. This researcher recommends against choosing a Schmidt et al. derived survey given the maturity of reliability and validity research on TPACK self-assessment instruments now available. See the Data Set.

Researchers who are interested in an instrument that has been extensively studied using factor analysis may want to consider the instruments developed by the research team of Chai, Koh, and others (2010 – 2019). Eight studies (see the Data Set) have obtained the expected 7-factor structure using an instrument by this research team in populations in China, Indonesia, Singapore, and Taiwan. The research team of Chai, Koh, and others (2010 – 2019) have engaged in a long-term research strategy of their instrument. They have slowly changed it from the Schmidt et al. (2009) structure, by generalizing the CK items while focusing pedagogical items using a constructivist philosophy, and changing the technology-based items to reflect newer technologies (see a detailed study of this in Scott, 2018). To date, the instruments from this team have been the most thoroughly studied in the literature showing consistent validity and reliability across numerous studies. Advantages to using an instrument from this stream of research include its incremental changes of CK-items to focus on constructivist pedagogies and its incremental changes to TK-items to focus on emerging technologies, strong reliability and validity studies, its use in a variety of faculty statuses and levels, and easy customization potential for CK-related items. Potential disadvantages include its constructivist pedagogical approach in recent studies and technologies which may become outdated.

The instrument from Sahin (2011) appears to be promising. It is a 47-item instrument that is a suitable for any discipline, is pedagogically agnostic, and focuses on standard technologies. Two EFA analyses (Bulut & Isiksal-Bostan, 2019; Sahin, 2011) have successfully extracted the 7-factor solution. The only factor analytics studies using this instrument have been in Turkey. The instrument has been used in the U.S., Indonesia, Iran, Pakistan, and Taiwan but no other EFA study has been conducted. Advantages to using this survey include its generic CK items, its TK item focus on established technologies, PK items that are pedagogically agnostic, and use in both pre-service and in-service teachers. Potential disadvantages include TK items that are specific, potentially outdated and needing revision, and lack of reliability and validity studies in geographically wide samples.

For researchers interested in the Yurdakul et al. (2012) conception of TPACK, two studies conducted EFA or CFA, both of them in pre-service Turkish teachers. Arslan (2015) conducted a CFA without using an *a priori* factor structure and confirming Yurdakul et al. Most other statistical analytic studies using Yurdakul et al. have been conducted in Turkey. Drummond and Sweeney (2017) used it in a study of 93 pre-service teachers in Australia and Xiaobin, Wei, Huiwen, and Lijin (2014)

used it in a study of 147 in-service elementary and middle school teachers in China. Neither study had a sufficient N to conduct an EFA (e.g., Kline, 2016; Thompson, 2004). Advantages to using this instrument include a focus on TPACK as a single construct with different competency-based factors. Disadvantages include lack of studies in geographically diverse populations and it does not measure the 7-factors as hypothesized by Mishra and Koehler (2006).

When searching for an instrument for their research, scholars may want to use the complete data set used for this article. See Data Set section. Researchers may want to prioritize measures that have been proven both reliable and valid, that measure the constructs of interest, that include item types desired (e.g., discipline, technology), that have been previously used in their target population (e.g., status, level, discipline, location), and do not conflict with the pedagogical practices of their target population (e.g., constructivist). Despite the large number of instruments available, researchers may not be able to find a survey that meets all the above criteria.

When searching for an instrument, this scholar recommends first locating a survey with item types that measure the desired constructs within the confines of knowledge, skill, and leadership; discipline-specific; or technology-specific items needed or items that can be easily customized (cf. Chen & Jang, 2013; Jang & Tsai, 2012). It is recommended that researchers review PK-related and TK-related item fit with the target population's experience and understanding or those designed to measure research foci. For instance, using constructivist PK- related items with a target population that has never had training with that type of pedagogical practice or using innovative TK-related items with a target population that has only familiarity with standard technologies may result in split constructs, discriminate validity issues, and unreliable results. Next, measures that have been proven to collect reliable and valid data should be prioritized when possible and appropriate to the research goals. Before researchers choose an instrument for their study, it is recommended that they consider the factor analytic studies of the instrument in their population, including the quality of those studies as indicated by the N and RTI. Researchers should use measures with multiple failed factor analyses with caution. When multiple options still exist, scholars should consider the status, level, discipline, and location of the sample populations with which the survey has been used (Figure 4).

RECOMMENDATIONS FOR FUTURE RESEARCH

Future researchers will want to examine the literature carefully for instruments that have been created and show promise (e.g., Sahin, 2011) and test them in new populations. These types of studies will help identify which instruments might be used in more diverse populations and which may be more culturally specific. Researchers may wish to examine the literature for instruments that have been used in studies but have never undergone a factor analytic study. This would allow them to establish

Figure 4. Recommended steps in selecting a TPACK instrument
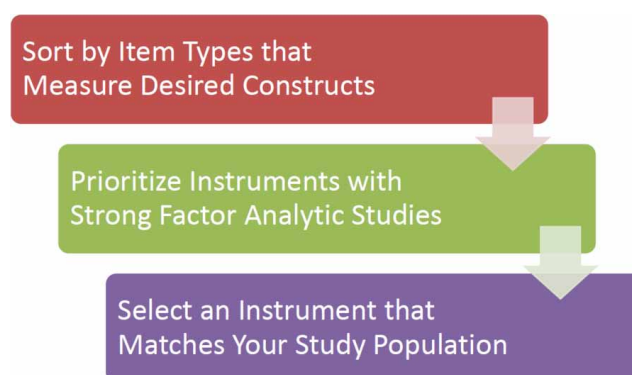
the validity and reliability of the scale for future scholars. Scholars may be interested in conducting an evaluation of survey items types or anchor types used with TPACK self-assessment surveys. Researchers may want to look to new ways of gathering samples to do large scale studies, in under-represented populations, and in disparate locations. Larger scale studies allow researchers to conduct more types of statistical analyses (e.g., EFA, CFA, SEM) and allow the body of literature to represent the total population of faculty more accurately.

LIMITATIONS

This study was limited to articles identified from the ERIC, Web of Science, Scopus, and PsycINFO databases. These databases were searched for peer-reviewed articles from January 2006 – March 2020 that were in English and used the terms "technological pedagogical content knowledge," "TPACK," or "TPCK" in their titles. As noted in the methodology section, 19 articles could not be obtained from university libraries or interlibrary loan.

This study was limited to articles that used a TPACK survey instrument in its design. Qualitative studies were not included. This researcher categorized studies based on the primary, or first, instrument reported as a basis even though some studies may have combined more than one instrument. The coding of articles was conducted by a single author. It was enhanced by an iterative process with temporal separations; however, as there was no other check and re-check process, there may be some errors in coding.

Some assumptions about survey respondent location was made for a few studies as it was not specified in the overview of the study population in methodology sections of those articles. When necessary, the researcher assumed the study respondent location was the same as the authors' location. Locations were grouped together in regions when analyzing articles for respondent location.

This study does not evaluate the quality of statistical analyses beyond EFA and CFA studies. This study is limited to the analyses articles reported. Some SEM studies may only have been studies of the measurement model (CFA) instead of a full SEM study including both a measurement and path model.

CONCLUSION

The TPACK framework (Mishra & Koehler, 2006) has been extensively studied using survey instruments and quantitative analyses. Researchers have focused their studies on a few instruments with varying success. While it may be true that the constructs may still have some "fuzzy" boundaries (Cox & Graham, 2009; Graham, 2011) and the technology continues to shift (e.g., Cox & Graham, 2009; Graham, 2011; Mishra & Koehler, 2006), there are several instruments that have proven factorial structures. These instruments can be used "as is" in similar populations, as the basis for research that studies them in new populators, or as the basis for a revision. This review and the complete data set can be beneficial to researchers in selecting an instrument for their study.

DATA SET

The data set, *Technological Pedagogical Content Knowledge (TPACK) Self-Assessment Data Set (January 2006 – March 2020),* used in this article is the creation of the author. It was developed to locate a reliable and valid self-assessment of faculty TPACK for a quantitative research study. It was expanded to include additional categories to ease the location of quality instrumentation for other scholars given the large number of articles and instruments available. The method for data collection and exclusion is described in the Methods section of this article. After eliminations, a total of 233 articles were included for analysis and their records are available in the dataset. The initial spreadsheets contained only four fields: author(s), article title, journal title, and publication

year. To facilitate the evaluation of TPACK self-assessment instruments, the researcher added 41 additional fields (columns) were included such as whether or not the survey instrument is included in the article, respondent characteristics, factor analytics data, anchors, and sample items, among many others. The data set is available for use, with proper citation, by other researchers at https://data.mendeley.com/datasets/9gcrpt6tpt/1.

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