RESEARCH ARTICLE

# Alignment of the synthesis of quality data (SQD) model, technology self-efficacy and TPACK Core measures in preparing pre-service teachers to integrate technology

## [version 1; peer review: awaiting peer review]

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## Abstract

Preparing pre-service teachers to integrate technology in their future classrooms is a complex endeavor. Several factors known to affect the use of technology in the classroom include technology knowledge and skills, positive attitudes toward integrating technology, pedagogical expertise with technology and content knowledge in one or more disciplines. One strategy that has been used in many educator preparation programs has been to create a course that teaches how to integrate technology. Measuring the impact of these types of courses is important in determining whether they are meeting the needs of the pre-service teachers in their pursuit to integrate technology in a meaningful and effective way. This paper reports on the measurement and alignment of three aspects that impact pre-service technology integration - technology self-efficacy, strategies and experiences provided by the preparation programs, and the intersection of technology, content knowledge and pedagogy. Pre-service participants in a semester-long course focused on integrating technology gained significantly from pre to post on each of the scales, demonstrating an increase in technology self-efficacy, experiences related to technology during their program and confidence in fusing technology, content knowledge and pedagogy. In addition, the three measures focused on different areas of technology integration aligned to show relationships of the attributes important for using technology in their future classrooms.

## Keywords

technology self-efficacy, pre-service education, technology integration, technology integration measures, SQD, TPACK

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## Introduction

Preparing future teachers to integrate technology in a thoughtful, reflective way is important in order to impact learning via technology. While many are advocating to no longer have a stand-alone technology integration course, this can be a valuable asset to a teacher preparation program if the course is approached in a contextual, content-focused manner that involves pedagogical reasoning for the use of technology in instruction (Loughran, 2019). Exploring best practices and models for ensuring that pre-service teachers are prepared to teach in a 21st century classroom is the first step in systematically and systemically creating a program that is responsive to this need. This paper addresses the alignment of technology self-efficacy, the SQD (synthesis of qualitative data) strategies and a Technological Pedagogical and Content Knowledge (TPACK)-related measure in the context of a course for technology integration within teacher education.

### Literature review

The preparation of teachers has been recognized as a critical ingredient for the integration of technology into the classroom (Dawson *et al.,* 2013; Tondeur *et al.,* 2012). Preparing teachers to use technology in an effective way is critical to the impact they will have in the classroom. Technology integration proficiency is a multifaceted attribute of an individual teacher that involves technology knowledge and skills, and confidence in the knowledge and skills, attitudes, and pedagogical expertise, merged together with content knowledge in a discipline.

Researchers have investigated the factors affecting teachers' use of digital technology in the classroom and concluded that pre-service training in technology led to better skilled teachers with the right attitudes to promote the use of technology in the curriculum (Spiteri & Rundgren, 2018). Modeling tools and strategies of technology integration and providing opportunities to practice these skills in authentic environments are important components in pre-service teacher education (Kavanagh *et al.,* 2020; Tondeur *et al.,* 2016). Having pre-service students design, reflect and receive feedback on instruction that includes technology integration builds confidence.

Pre-service teachers' technology integration behaviors are impacted by their beliefs in the value of technology and their personal efficacy with it (Ertmer & Ottenbreit-Leftwich, 2010). Self-efficacy has been defined as confidence in one's competence (Christensen & Knezek, 2017) and is a factor that influences the effectiveness of teaching with technology (Hoy *et al.,* 2009). According to Bandura (1993), self-efficacy is a good predictor of behavior. Oliver & Shapiro (1993) found teachers' self-efficacy beliefs to be indicators of success for technology integration.

In addition to self-efficacy, skills and attitudes toward technology, there are additional components provided by the preparation programs that are known to impact pre-service teachers' classroom technology integration. Tondeur and colleagues (2016) describe six strategies that have been shown to be key components of technology integration for pre-service teachers. These six strategies include: Role models, Authentic experiences, Feedback, Reflection, Instructional design and Collaboration. Each of these is described more fully later in this paper.

Teacher preparation programs serve a critical role in creating opportunities for pre-service teachers to learn how to confidently integrate technology into instruction when they leave the program and enter the teaching field. There are many approaches, ranging from technology infusion throughout all teacher education courses to individual courses focused primarily on technology skills. Even the individual courses vary greatly in their impact depending on the focus of the course (Abbitt & Klett, 2007). Aligning a technology integration course with educational technology standards focused on higher level ideas rather than technology use skills can be one way to ensure the course is of value in preparing future teachers to integrate technology (Abbitt & Klett, 2007; Christensen, 2021; Lee & Lee, 2014). This paper addresses the pre-post changes that occurred during a course focused on technology integration. In addition, this paper explores the relationships between measures of technology self-efficacy, the Synthesis of Qualitative Data (SQD) Model for teacher preparation and TPACK Core.

### Theoretical background

Models of technology integration allow researchers and practitioners to understand the components that are needed to successfully integrate technology for teaching and learning. One model that includes the complexity of many of the components required for success is the synthesis of qualitative data (SQD) model. This model was developed with the goal of creating an evidence-based model to inform teacher education programs. Tondeur *et al.* (2012) reviewed more than a dozen qualitative studies in the quest to create a model that included methods to best prepare pre-service teachers to integrate technology.

The SQD model includes three interrelated levels necessary for preparing pre-service teachers for technology integration (Tondeur *et al.,* 2012). Figure 1 shows the SQD's three levels that are all critical components of sustained, effective technology integration. The outer level of the model includes the systematic and systemic change efforts that rely on evidence that aligns theory and practice. The second level includes the components that support the educator in the classroom with planning and leadership, resources, training and professional development. In addition, the second level includes cooperation within and between institutions which is an important element in preparing teachers to use technology within the clinical experiences they encounter. The third level is related to the experiences that need to be present in a teacher preparation program to ensure the candidates are prepared to use technology effectively and appropriately in the classroom. These six strategies include: Role models, Reflection, Instructional design, Collaboration, Authentic experiences and Feedback. The three interrelated SQD levels are similar to the macro (large systems), meso

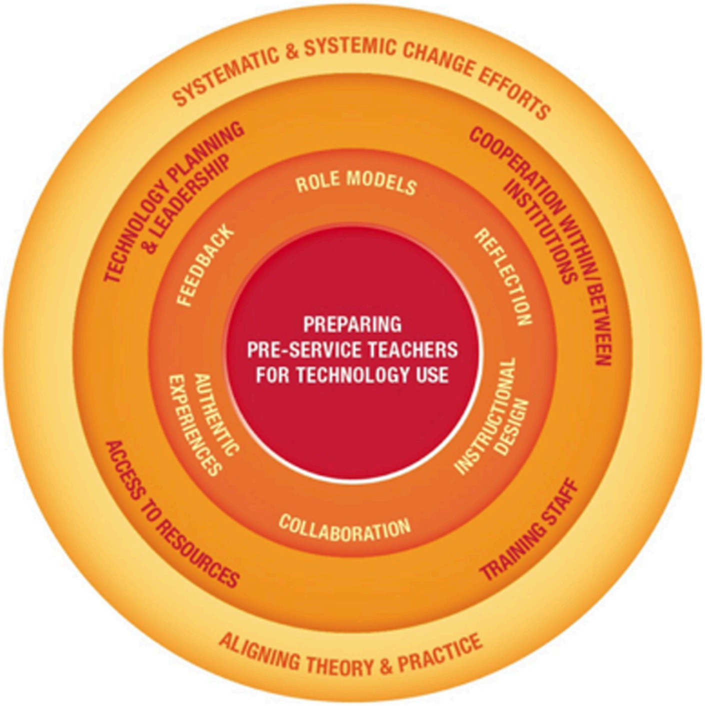

**Figure 1. Synthesis of Qualitative Data (SQD) model to prepare pre-service teachers for technology use (Tondeur *et al.,* 2012).**

(schools and leadership), and micro (classroom/teacher) level approach (Pelgrum *et al.,* 1993) that recognizes the substantial interdependencies among multiple systems and actors. While all three levels of the SQD are important, this paper will focus on the six strategies measured using self-report survey data from pre-service teachers.

The TPACK framework is focused on the intersection of technology integration in content areas using appropriate pedagogies. TPACK has been used in the educational research field for more than a decade as a theoretical framework for understanding the relationship between teacher knowledge and effective technology integration (Mishra & Koehler, 2006) and is intended to focus on the relationship between the three kinds of knowledge addressed: technology, pedagogy, and content (Thompson & Mishra, 2007–2008). The TPACK framework builds on Shulman's construct of pedagogical content knowledge (PCK) (Shulman, 1986) to include technology knowledge as situated within content and pedagogical knowledge. A TPACK instrument was developed that includes 75 items and spans seven TPACK domains (Schmidt *et al.*, 2009). More recently, Fisser, Voogt, Tondeur, and van Braak (2013) created an eight-item scale (TPACK Core) adapted from the original TPACK survey with a focus on the central concepts of the TPACK framework.

In addition to technology knowledge, teacher technology self-efficacy is another important component for integrating technology. Self-efficacy is based on Bandura's (1977, 1986) social development theory, and has been defined as the beliefs of individuals related to their own aptitude to perform a certain behavior (Gencturk *et al.,* 2010). Teacher self-efficacy contributes to a classroom teacher's success or failure (Henson, 2003) and has also been found to be an indicator for the successful integration of technology into the classroom (Compeau *et al.,* 1999; Ertmer, 1999; Ertmer, 2005; Oliver & Shapiro, 1993). The authors of the current study operated with the definition of self-efficacy as *confidence in one's competence*.

While there are many facets that impact technology integration (attitudes, beliefs, access), this paper focuses on teacher self-efficacy with technology, the perceptions of pre-service teacher experiences in their program regarding technology integration and the intersection of technology with content knowledge and pedagogy. This paper will investigate the pre-post changes that occurred during a semester-long, technology integration course designed for pre-service educators. In addition, the paper explores the relationships between the three factors of the Technology Proficiency Survey for Educators (TPSE) survey for self-efficacy, the six SQD strategies and TPACK Core.

## Research questions

Understanding how the implementation of a technology integration course impacts pre-service teachers' technology self-efficacy, experiences with technology and knowledge to integrate technology into the content is important for both educator preparation programs but also accrediting agencies. To further understand the impact of efforts to prepare pre-service teachers to integrate technology, this research was guided by the following research questions:

- To what extent do measures of teacher technology self-efficacy, TPACK Core, and SQD domains change pre to post over the period of a semester-long technology integration course?
- To what extent do teacher technology self-efficacy, SQD domain and TPACK core measures align with one another?
- To what extent do pre-service teachers display aligned patterns of technology self-efficacy, TPACK Core and SQD over the period of a semester-long technology integration course?

## Methods

### Participants

Data were collected from pre-service students as a course assessment for a required educational technology course in a teacher preparation program located in the southwest part of the US. The course was offered in various formats depending on the coronavirus disease (COVID-19) restrictions in place but was typically offered as a blended format (some synchronous classes either online or face to face) and was taught through a learning management system and video conferencing system (when online synchronously). Data from 197 pre-service teachers were gathered pre and post over six semesters between fall 2019 and spring 2022 on instruments described in the paper.

Demographics related to these participants were also gathered through self-report, online surveys. The response to gender inquiry included 52 males (26.5%) and 144 females (73.5%) with a mean age = 27 (range of 19 to 61) with 62.43% being age 25 or younger. Many of the participants were in their last semester of the program and were concurrently completing their clinical teaching (n = 77, 39%). Participants were asked to respond to the grade level band to which they intended to teach. The categories and frequencies are shown in Table 1.

**Table 1. Participants Intended Grade Level to Teach.**

| Level Plan to Teach | N | Percent |
|---|---|---|
| PreK-2 | 60 | 30.5 |
| Grades 3 – 5 | 37 | 18.8 |
| Grades 6–9 | 29 | 14.7 |
| Grades 9–12 | 67 | 34.0 |
| Other | 4 | 2.0 |
| Total | 197 | 100.0 |

### Intervention/focus of study

The course content focused on how to integrate technology into the classroom to impact learning and was designed to address the International Society for Technology in Education (ISTE) standards for educators (2017) that include seven broad categories: Learner, Leader, Citizen, Collaborator, Designer, Facilitator, and Analyst. Moreover, while the course was not developed with the SQD strategies in mind, the strategies were woven throughout the course.

Four assignments and weekly activities culminated in a final electronic portfolio that included a unit plan with technology integrated lessons as well as a reflection on their learning about using technology in the classroom during the semester. This organization connects closely with ISTE standards for Designer and Analyst, as well as SQD dimensions of Instructional design and Reflection.

Many of the tools and strategies introduced and experienced in the course were included in the unit plans. Students used tools such as *Adobe Spark* or *iMovie* for digital storytelling, *BrainPop* to teach digital citizenship, *Thinglink* to create non-linear multi-media topic-based activities, *Scratch* for introduction to computational thinking, *Whyville* for introducing various topics with games and simulations, and augmented and virtual reality for visualization of content. Student exploration of technological tools for education was modeled by the instructor (see SQD Role Model). For example, *Padlet* was used in the class discussion related to digital citizenship which demonstrated one way to use this collaborative tool for learning purposes.

At the beginning of the semester, students explored and selected a content area topic and grade level in which they focused the development of a unit plan that included activities that integrated technology tools. The instructional design task aligned with the SQD Instructional Design strategy and required the students to share each of the artifacts along with the unit plan via an electronic portfolio. Student comments revealed their understanding of the importance of designing meaningful instruction as opposed to focusing on the technology.

> *I believe whatever technology is chosen or designed to use in the classroom, it must align with the learning objectives so that students can become deeply engaged in learning and consequently accomplishing the learning goals.* (student end-of-semester reflection)

The students were also required to include an essential question that required them to focus at a higher level of thinking toward the creation of the unit plans. Collaboration between peers was encouraged, also in alignment with the SQD Collaboration strategy, as a way to provide an effective low threat learning environment (Lee & Lee, 2014). Students created a unit plan that spanned three weeks of lessons focused on the topic they selected. In addition to the essential question, students included unit questions, content and technology standards, objectives, activities, differentiated instruction and assessment tools. During the exploration of technology tools, students submitted sample activities and how they might use the tools for their unit.

For each activity in the unit that included technology, the students were required to include the PIC-RAT (passive, interactive, creative - replacement, amplification, transformation) classification (Kimmons *et al.,* 2020) and reflect on the reasoning behind their selections as it related to teacher use of technology as well as student use of technology. The PIC part of the model refers to the student's relationship to a technology for the lesson while the RAT part of the model describes the impact of the technology on a teacher's previous practice (Kimmons *et al*., 2020). In addition, in response to an open-ended reflection component, many of the students reflected on their growth throughout the semester – in aligning with the SQD Reflection strategy. One example of a student reflection was related directly to their own reflective practices using PIC-RAT and their prior experiences with technology role models. The student reflected:

> *When I was in school, technology was mainly used in the "Replaces" category of the PIC-RAT matrix. I could count on my hands how many times the teacher's use of technology amplified a traditional practice. I'm so excited to have many resources that will help me to amplify and even transform traditional teaching in the years ahead so that my students can have a better experience with technology than I did. That will set them up for success when they enter the real world.*

Feedback was provided on each activity in alignment with the SQD Feedback strategy, often allowing students to make changes and resubmit their activities based on the feedback. Feedback such as use of forums, Flipgrid video responses and other appropriate tools that allowed feedback by both the instructor and peers also provided a role modeling of how they can be used with their future students.

There were no required textbooks and the course content, materials and resources were all selected by the instructor and available online through the learning management system as open educational resources to the students. The instructor identified apps and tools that were readily accessible to all students, available for free or brief educational trial, and they were given choices of tools to use. While it was more challenging for the instructor, it was more of a reality of what they would likely encounter as classroom teachers. While online tutorials were often linked as aids in using different tools, classroom meetings did not include the teaching of skills for individual software or technology tools, but was focused on how these tools could be used to enhance classroom instruction.

Finally, most of the preservice teachers were simultaneously enrolled in courses that required classroom observation and involvement, and more than one-third (39%) were completing their clinical teaching experience which allowed them to have (SQD) authentic experiences integrating what they were learning during their educator preparation program. As one student commented:

> *The information I've learned in this class has been so useful and helpful, that I've been able to integrate some of the technology I've learned in this class in my lesson plans for my student teaching. For example, we were learning about the properties of rocks in science one week. I handed students a bag of 5–8 rocks that were all different in shape, color, size, and texture. They had to create a Flipgrid video describing each rock using the 5 physical properties (color, shape, size, texture, and flexibility). [...] They were able to post their videos and watch all their classmates' videos. It just made them be so much more engaged than if I would've had them draw their rock and describe it on paper.*

## Instrumentation

Data were collected (Christensen, 2022) to determine the impact of the course and used to provide informative feedback to the instructors and educator preparation program for on-going quality assessment. Students completed pre-post surveys designed to measure dispositions and experiences related to technology integration. While additional survey data were collected, the surveys used in this study were the TPSE (Christensen, 2021), the SQD (Tondeur *et al*., 2016), and the TPACK Core scale (Fisser *et al.,* 2013). Open-ended reflective feedback was provided by the students at the end of the semester which provided a richer qualitative aspect of the quantitative findings. The items for each of the surveys is included in the *Extended data* (Christensen, 2022).

The Technology Proficiency Survey for Educators survey is based on the ISTE standards for educators (2017) measuring technology self-efficacy. The TPSE was created as a pre-post assessment measure for a pre-service course focused on technology integration in the classroom (Christensen, 2021). Sixteen of the items were created by the first author based on the seven categories of the ISTE standards for educators (Christensen, 2021). The seven categories included: Learner, Leader, Citizen, Collaborator, Designer, Facilitator, and Analyst. Six of the items were from previous work by one of the authors on instruments used for measuring teacher technology efficacy (Christensen & Knezek, 2017). Each of the 22 items followed the stem, "I feel confident I could…". The participants were asked to respond to their level of agreement to each of the 22 items from a level of 1 = Strongly Disagree to 5 = Strongly Agree. The TPSE includes three factors from the 22 items. Factor 1 is related to designing, creating and modeling learning with technology. Factor 2 items are related to communicating and collaborating with technology. Factor 3 is related to extending learning beyond the classroom using technology. Cronbach alphas ranged from .77 to .94 and are shown in Table 2 along with the estimated reliability alphas for the other scales.

**Table 2. Estimated Reliabilities for Each Scale of the Technology Proficiency Survey for Educators (TPSE), Synthesis of Qualitative Data (SQD) and Technology Pedagogy and Content Knowledge (TPACK.**

| Scale | Cronbach's Alpha | Number of Items |
|---|---|---|
| TPSE Factor 1 | .936 | 10 |
| TPSE Factor 2 | .872 | 7 |
| TPSE Factor 3 | .767 | 5 |
| SQD Role Model | .915 | 4 |
| SQD Reflection | .881 | 4 |
| SQD Instructional Design | .939 | 4 |
| SQD Collaborate | .887 | 4 |
| SQD Authentic Experiences | .827 | 4 |
| SQD Feedback | .931 | 4 |
| TPACK Core | .961 | 8 |

The SQD questionnaire items were adapted from the SQD Model (Tondeur *et al.,* 2016). These items were developed based on assessing effective strategies needed to prepare future teachers. The SQD scale consists of six parts related to self-reported experiences that occurred during their pre-service program training. The six domains of the SQD include Role Model, Reflection, Instructional Design, Collaboration, Authentic Experiences and Feedback. Role Model is a measure of seeing examples of technology use in educational settings that may have inspired the individual to use these tools for themselves. Reflection includes the opportunity to discuss experiences creating and/or using technology for classroom learning. Instructional Design reflected the amount of help the future teacher received in designing technology-rich learning materials. Collaboration items related to sharing technology information as well as working with others to develop technology-enriched experiences. Feedback items were related to the amount of feedback students received regarding technology competencies and use. Authentic Experiences items were used to measure the amount of opportunity pre-service students received in testing their technology activities in educational settings and trying out their technology activities in authentic settings. The participants were asked to respond to their level of agreement to each of the 24 items from a level of 1 = Strongly Disagree to 5 = Strongly Agree. Each of the scales contained four items and were found to have high Cronbach's alpha reliabilities as shown in Table 2.

Another measure of technology integration completed by participants was the TPACK Core scale. This scale is one part of the TPACK survey that appears to be most related to the intersection of content, technology and pedagogy (Fisser *et al.,* 2013). Estimated reliabilities for this set of data were excellent and shown in Table 2.

Cronbach's reliability estimates were calculated on the data set for each of the scales and are shown in Table 2. The estimated reliabilities ranged from .77 to .96 considered to range from "respectable to "excellent" according to the DeVellis (2012) guidelines.

## Results

Results of pre-post analyses are reported for each of the described survey instruments followed by the relationship of these items as it relates to preparing future teachers to integrate technology in a meaningful and reflective way. As shown in Table 3, each of the scales of the TPSE were significantly ($p$ <.05) higher from pretest (beginning of the semester) to posttest (end of the semester). The measures align with the goals of the course and the analyses appear to support the intention. While the SQD Model was not used to guide the development or teaching of the course, each of the six domains aligns strongly with the course objectives and outcomes. As shown in Table 3, all six of the domain scales increased significantly ($p$ <.05) from pre to post test. In addition, TPACK Core, which is focused on the intersection of content, technology and pedagogy, also increased significantly ($p$ <.05) from pre to posttest (Table 3). Effect sizes were calculated for each of the scales because they provide information about the magnitude of the differences found, whereas statistical significance examines whether the findings are likely to be due to chance. As shown in Table 3, the magnitude of the pre to post gain effect sizes ranged from .88 to 1.75, which is large according to guidelines by Cohen (1988), well beyond the effect size = .3 criteria for an effect that is normally considered educationally meaningful (Bialo & Sivin-Kachala, 1996), and well within the zone of desired effects according to modern psychometric standards (Lenhard & Lenhard, 2016). Each of the pre-post means are graphically displayed in Figure 2.

### Relationship of multiple measures

To evaluate the relationship between the measures, a Pearson product-moment correlation was computed using the six SQD strategy scales, the TPACK Core and the three TPSE scales. There was a significant ($p$ <.01) correlation between the three subscales of the TPSE, TPACK Core and each of six SQD strategy scales.

As shown in Table 4, TPSE F1 (related to designing, creating and modeling learning with technology) was *strongly* (.5 or greater) correlated with SQD Instructional Design (.563), SQD Authentic Experiences (.508) and TPACK Core (.717). TPSE F2 (related to communication and collaboration using technology) was *strongly* correlated with SQD Instructional Design (.571), SQD Authentic Experiences (.525), and TPACK Core (.691). TPSE F3 (related to extending learning beyond the classroom) was *strongly* correlated with SQD Instructional Design (.526), SQD Authentic

**Table 3.** **Pre-post Descriptive Statistics for all Measures.**

| Measurement Scales | | N | Mean | Std. Dev | Sig. | ES |
|---|---|---|---|---|---|---|
| Technology Proficiency Self Efficacy Scales | | | | | | |
| TPSE Factor 1<br>Design, create and model learning with technology | Pre | 197 | 4.15 | .71 | | |
| | Post | 187 | 4.70 | .43 | | |
| | Total | 384 | 4.42 | .65 | .000 | .93 |
| TPSE Factor 2<br>Communicate and collaborate using technology | Pre | 197 | 4.19 | .69 | | |
| | Post | 187 | 4.69 | .40 | | |
| | Total | 384 | 4.43 | .62 | .000 | .88 |
| TPSE Factor 3<br>Extending learning beyond the classroom with technology | Pre | 197 | 3.81 | .75 | | |
| | Post | 187 | 4.43 | .54 | | |
| | Total | 384 | 4.11 | .73 | .000 | .95 |
| Synthesis of Qualitative Data (SQD) Domain Scales | | | | | | |
| SQD Role Model | Pre | 197 | 3.82 | .92 | | |
| | Post | 187 | 4.63 | .55 | | |
| | Total | 384 | 4.22 | .86 | .000 | 1.06 |
| SQD Reflection | Pre | 197 | 3.31 | .99 | | |
| | Post | 187 | 4.54 | .61 | | |
| | Total | 384 | 3.91 | 1.03 | .000 | 1.49 |
| SQD Instructional Design | Pre | 197 | 2.92 | 1.08 | | |
| | Post | 187 | 4.51 | .68 | | |
| | Total | 384 | 3.69 | 1.21 | .000 | 1.75 |
| SQD Collaborate | Pre | 197 | 3.32 | 1.00 | | |
| | Post | 187 | 4.37 | .71 | | |
| | Total | 384 | 3.83 | 1.02 | .000 | 1.21 |
| SQD Authentic Experiences | Pre | 197 | 3.34 | .92 | | |
| | Post | 187 | 4.47 | .63 | | |
| | Total | 384 | 3.89 | .97 | .000 | 1.43 |
| SQD Feedback | Pre | 197 | 2.79 | 1.10 | | |
| | Post | 187 | 4.35 | .84 | | |
| | Total | 384 | 3.55 | 1.25 | .000 | 1.59 |
| Technology Pedagogy and Content Knowledge (TPACK) Core Scale | | | | | | |
| | Pre | 129 | 3.52 | .95 | | |
| | Post | 105 | 4.65 | .48 | | |
| | Total | 234 | 4.03 | .96 | .000 | 1.49 |

Experiences (.502) and TPACK Core (.555). Finally, TPACK Core was *strongly* correlated with SQD Instructional Design (.589), SQD Authentic Experiences (.512), and SQD Feedback (.515). In addition to the reported strongly correlated relationships, there were also many moderately (.3 to .5) strong relationships among the scales. While each of the instruments aimed at a different focus of technology integration, they were strongly related to one another.

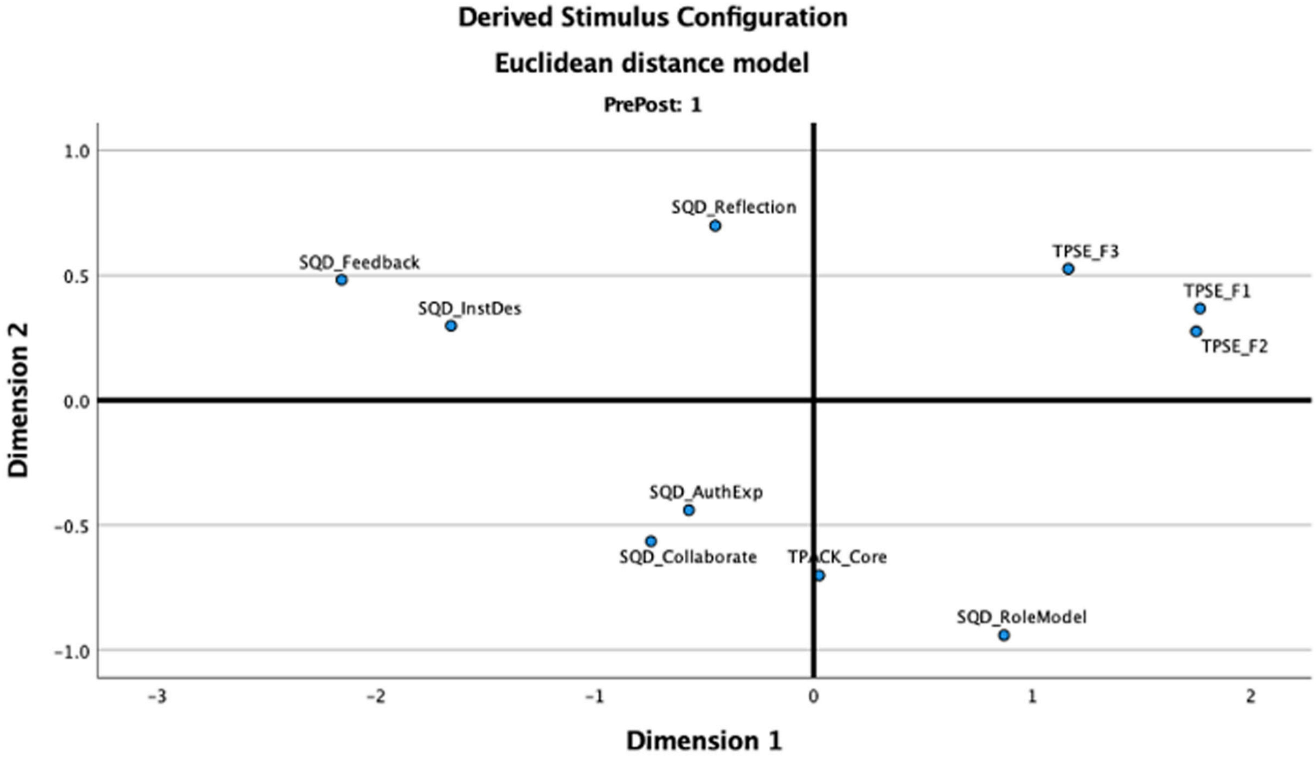

**Figure 2.** **Pre-post means for the 10 subscale measures.**

**Table 4.** **Pearson Product Moment Correlations for All Measures.**

| | | SQD Role Model | SQD Reflection | SQD Inst Des | SQD Collaborate | SQD Auth Exp | SQD Feedback | TPACK Core |
|---|---|---|---|---|---|---|---|---|
| TPSE F1 | Pearson Correlation | .468** | .456** | .563** | .447** | .508** | .390** | .717** |
| TPSE F2 | Pearson Correlation | .439** | .479** | .571** | .477** | .525** | .412** | .691** |
| TPSE F3 | Pearson Correlation | .386** | .461** | .526** | .470** | .502** | .386** | .555** |
| TPACK Core | Pearson Correlation | .383** | .439** | .589** | .440** | .512** | .515** | |

Note: ** Significant (2-tailed) at p <.01; Technology Proficiency Survey for Educators (TPSE), Synthesis of Qualitative Data (SQD) and Technology Pedagogy and Content Knowledge (TPACK)

## Alignment of SQD with other measures

While the course was not developed with the SQD strategies in mind, the strategies were woven throughout the course and seemed to align with the teacher technology self-efficacy measures that were based on the course content. One technique to show relationships among indices is multidimensional scaling (MDS). In MDS, the goal is to determine the smallest number of dimensions that are necessary to accurately represent the psychometric distances between the items rated by survey respondents (Dunn-Rankin *et al.,* 2004). ALSCAL was chosen as the scaling method because it produces an R-squared estimate of total variance explained, which is directly comparable to R-squared values commonly reported for regression analysis. In this study, the specific reason for using MDS was to determine the alignment of the multiple measures as well as whether there were any changes in the dimensional constructs of the scales from pre to posttest time.

Both 1- and 2-dimensional solutions were calculated but the 2-dimensional solution was selected to include because the RSQ was above .80 at both pre and posttest time for the 2-dimensional solution (RSQ .946 at pretest and RSQ = .810 at posttest time). The TPACK Core scale changed alignment from pretest to posttest from being more aligned with SQD at pretest time (Figure 2) to more aligned with TPSE scales at posttest time (Figure 3).

While MDS accounts for the psychometric distances between the survey items, two-step cluster analysis techniques were used to uncover alignment of the different scales on an individual respondent basis, over time. Pretest and posttest TPSE, TPACK Core and SQD data were considered independently in the cluster analysis and highlighted different patterns of participants' responses to the survey.

The participants' profiles showed unique scores in TPSE, TPACK Core and SQD scales at pretest. Figure 4 shows the three emergent clusters at pretest. Participants affiliating with *Cluster one* (i.e. profile one, n=60, 47%) scored on the higher end of the Likert scale on each of the measures at pretest (means above 3.84 out of 5). On the contrary, *Cluster two* (n=36, 28%) scored on the lower end of the scale on every measure at pretest (means between 2.01 and 3.38 out of 5). Finally, *Cluster three* (n=33,26%) showed the most ambivalence in its scoring, with high self-efficacy measures (TPSE means above 4.09 out of 5), average TPACK Core mean (3.13) and below average SQD measures (means equal or under 3.49 out of 5).

In providing more descriptive names for each of the clusters, at pretest time, *Cluster one* participants appeared to be more "aware" and perhaps more "confident". *Cluster two* participants appeared to be more "naïve" when it came to using technology for education. *Cluster three* participants seemed to display more "ambivalence" or "skepticism" in the need to use technology in education, yet felt confident in their ability to use technology. Several of the reflections from students revealed a similar observation. As one student in cluster two reflected…

> *At the beginning of the semester, I was honestly a little bit skeptical about what this class could possibly teach me as someone who is usually very well versed with technology in general. I would soon come to find that there is an extremely huge difference in use of technology in daily life as compared to usage in education.*

Figure 5 shows the three emergent clusters at posttest. Each of the clusters scored on the higher end of the scale, confirming the significant changes between pretest and post-test shown previously in Table 3. Moreover, the new *Cluster one* (n = 62, 59%) scored extremely high on the Likert scale on all ten measures (means above 4.67 out of 5).

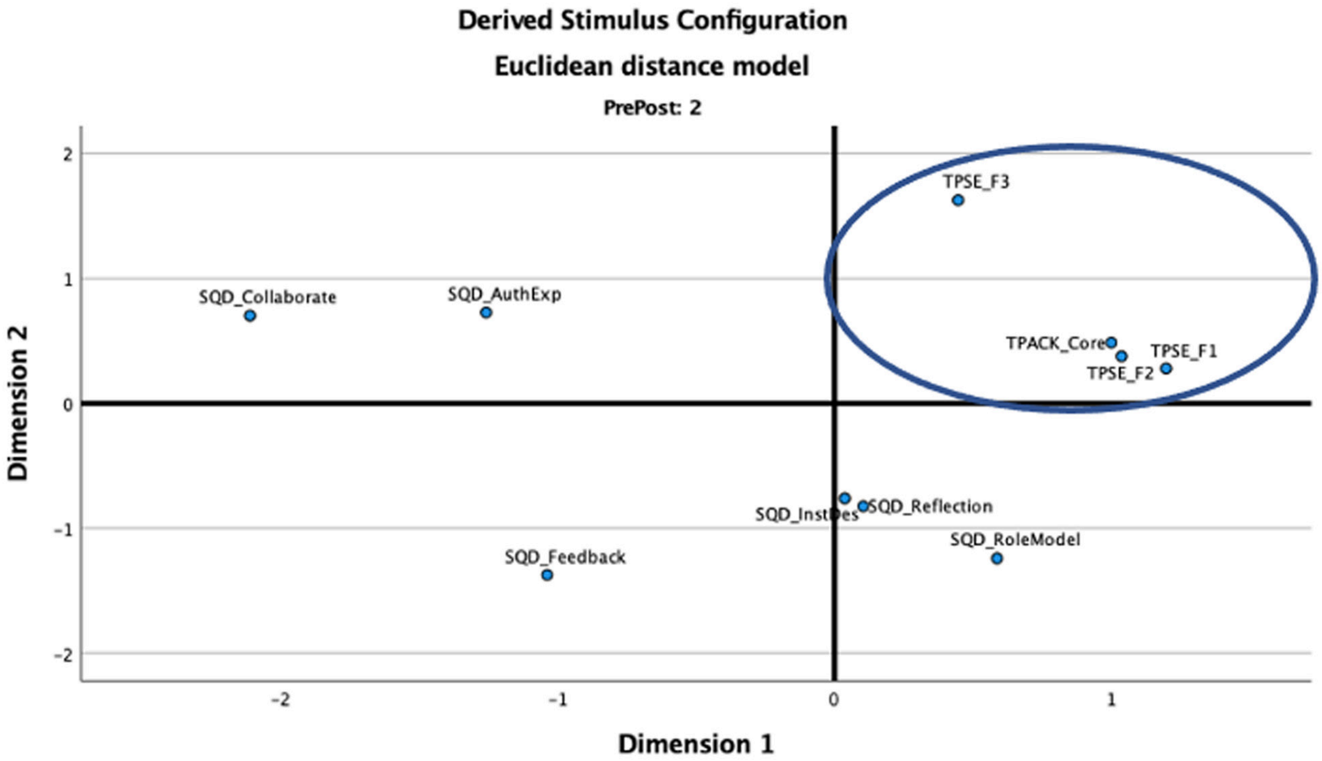

**Figure 3.** **Two-dimensional multi-dimensional scaling solution at posttest time.**

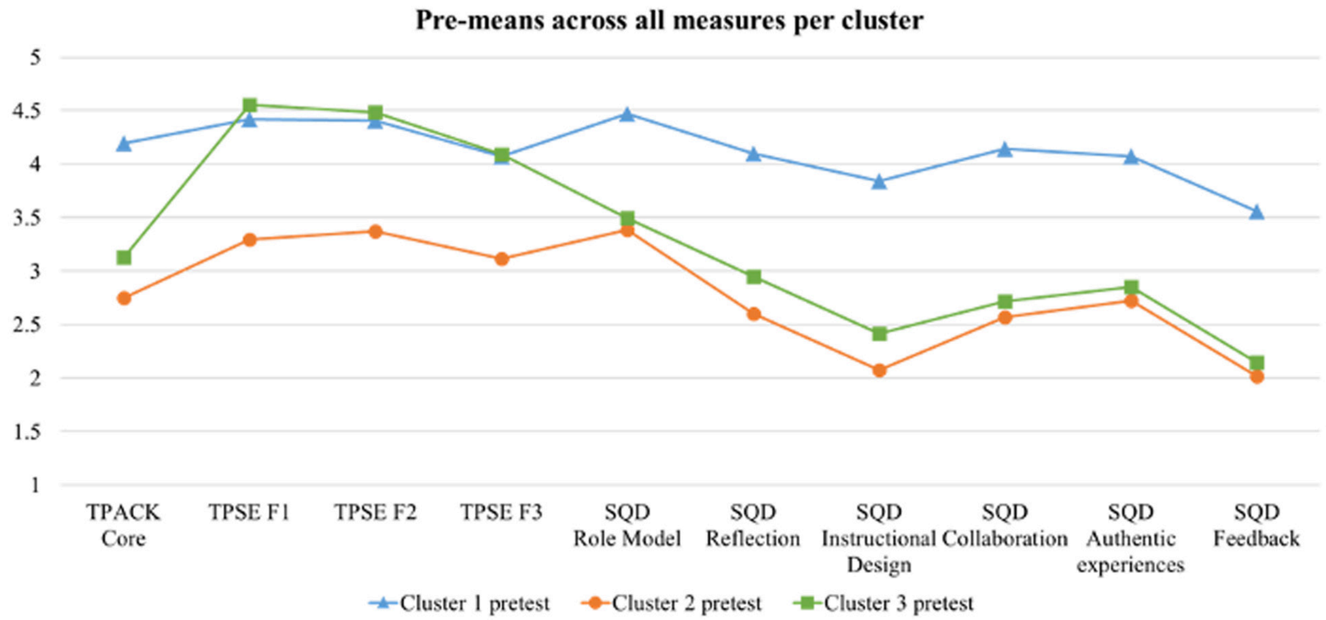

**Figure 4.** **Clusters' means across measures at pretest.**

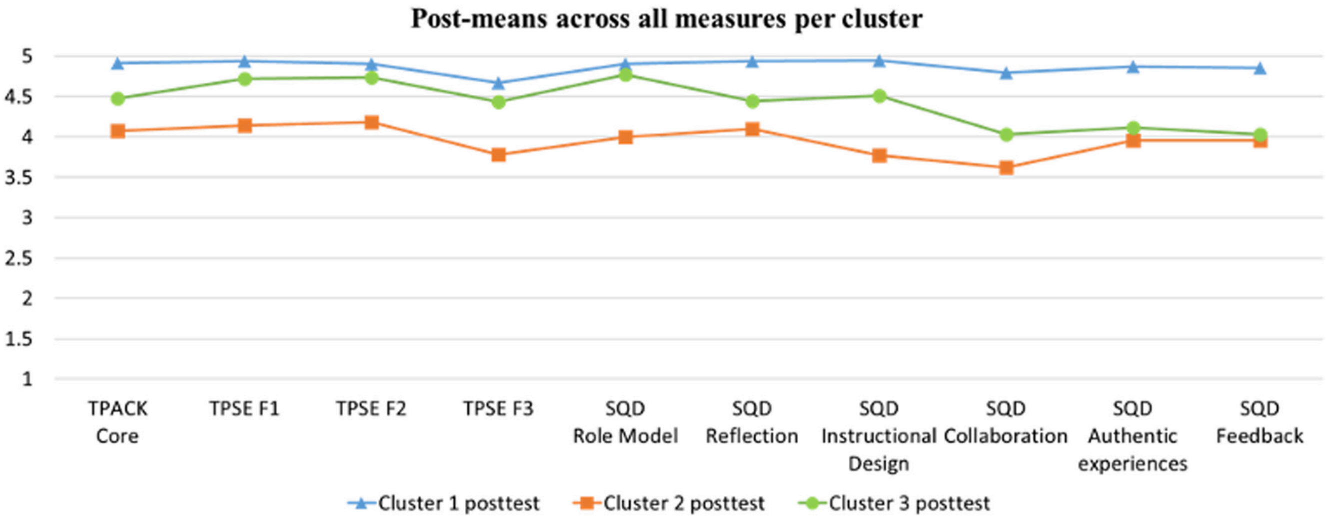

**Figure 5.** **Clusters' means across measures at posttest.**

On the contrary, the new *Cluster two* (n= 22, 21%) scored almost linearly lower on every measure (still means between 3.63 and 4.18 out of 5). Finally, the new *Cluster three* (n=21, 20%) aligned with middle scores on TPACK Core, TPSE scales and SQD dimensions (means between 4.04 and 4.77 out of 5). The patterns highlighted by the clusters and the low dispersion of data from the means in each cluster (standard deviation on all measures was < .6) further confirmed how individual approaches to one's own self-efficacy and TPACK core, as well as experiences in the course (SQD) aligned across all measures over the semester. At posttest there was no profile showing ambivalent scores in the different scales.

At posttest time, the cluster configurations changed in their description of their attributes. The participants who now gravitated to *Cluster one* appeared to be more "confident, accomplished and skillful" at integrating technology. *Cluster two* participants included those who were still high overall, but more "cautious". *Cluster three* participants were in the middle of all the measures.

While it is apparent that participants changed in their self-efficacy, reported experiences and integration of content, technology and pedagogy, it is not as clear what impacted the changes specifically. In the Cluster analysis, we could see how 32% of *Cluster one* at pretest remained in *Cluster* *one* at posttest, while only 13% of them joined *Cluster three* at posttest. Similarly, 44% of the members of *Cluster two* at pretest merged into *Cluster one* at posttest – although the second highest percentage of them (11%) joined *Cluster three* posttest with the lower scores. Finally, 49% of *Cluster three* at pretest moved all the way to *Cluster one* while 9% split in either *Cluster two* or *three*. To understand the dynamics underpinning the shift in cluster affiliation, it is helpful to look at the discriminant functions determining the clustering at pretest and posttest (Table 5).

Clusters at pretest were determined by two functions. Function one has an eigenvalue of 2.62, explaining 73.2% of the variance, and it discriminates primarily between *Cluster one* (confident - higher scores) and *Cluster two* (naïve - lower scores). This function is determined mainly by SQD and TPACK core variables. In order of absolute size of correlation within the function, there are: SQD Collaboration (*r* = .72), SQD Instructional Design (*r*= .69), SQD Authentic Experiences (*r*= .61), SQD Reflection (*r*= .60), SQD Feedback (*r*= .60), TPACK Core (*r*= .58), and SQD Role Model (*r*= .45). Function two at pretest has an eigenvalue of .96, explaining 26.8% of the variance, and identifying *Cluster three* (ambivalent scores). This function was determined mainly by TPSE scales. In order of absolute size of correlation within the function, the largest impact was TPSE F1 (*r* = .80), followed by TPSE F2 (*r*= .69), and finally TPSE F3 (*r*= .46).

At posttest, Clusters were determined by two new functions. Function one posttest has an eigenvalue of 7.02, explaining 89.9% of the variance, and it discriminates primarily between *Cluster one* (accomplished - higher scores) and *Cluster two* (cautious - low scores). This function was determined by a variety of SQD dimensions, TPSE scales and TPACK core variables. This result corroborates the correlation analysis previously discussed: the different measures at posttest combined to shape patterns of response. In order of absolute size of correlation within the function, there were: SQD Instructional Design (*r* = .52), TPSE F1 (*r*= *.48*), TPSE F2 (*r*= .44), SQD Collaboration (*r*= .38), TPACK Core, (r= .38), SQD Role Model (*r*= .37), SQD Reflection (*r*= .37), and TPSE F3 (*r*= .32). Function two at posttest had an eigenvalue of .79, explaining 10.1% of the variance, and it separated *Cluster three* (medium scores) from the other ones. This function was determined mainly by SQD Feedback (*r* = .49) and SQD Authentic Experiences (*r*= .44). Overall, the functions determining response patterns (i.e. clusters) changed over time in relation to their composition (homogeneous function composition at pretest, varied composition at posttest).

## Discussion

Reasons for the construct changes were likely related to student experiences during the semester. While pre-post analysis of variance demonstrates significant changes, additional analyses provided more nuances of how the changes may have occurred. The pre-service students entered the course at various levels of comfort, experience and confidence in integrating technology in the classroom. However, by the end of the course the students had shifted closer together in a more homogenous understanding of technology integration measured by the various factors that contributed to their changes. These findings are supported by multiple types of analyses including MDS showing changes in alignment of the scales from pre to post. In addition, cluster analysis techniques revealed individual respondent changes over time highlighting interesting patterns of change while discriminant function analysis indicated which of the measures determined the clusters.

## Summary and conclusions

To answer RQ1, *To what extent do measures of teacher technology self-efficacy, TPACK Core, and SQD domains change pre to post over the period of a semester-long technology integration course?* each of the different types of measures showed significant changes during the course of the semester indicating pre-service teachers felt more confident integrating technology within a content context using appropriate pedagogical approaches due to their experiences during the semester. Regarding RQ2, *To what extent do teacher technology self-efficacy, SQD domain and TPACK core measures align with one another?* the various scales of the measures aligned psychometrically as well as practically to provide meaningful clusters of individuals and their changes throughout a focused intervention. In answering

**Table 5.** **Descriptive Discriminant Function Analysis at Pretest and Posttest.**

| | | | | | Correlation variable – function | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Functions | | Canonical correlation | Eigenvalue | Variance explained (%) | TPACK Core | TPSE 1 | TPSE 2 | TPSE 3 | SQD Role Mode | SQD Reflection | SQD Inst Des | SQD Collaborate | SQD Auth Exp | SQD Feedback |
| Pre | 1 | .85 | 2.62 | 73.2 | .58* | .53 | .48 | .37 | .45* | .60* | .69* | .72* | .61* | .60* |
| | 2 | .70 | .96 | 26.8 | .10 | .80* | .69* | .46* | .18 | .13 | .19 | .30 | .25 | .26 |
| Post | 1 | .94 | 7.02 | 89.9 | .38* | .48* | .44* | .32* | .37* | .37* | .52* | .38* | .34 | .31 |
| | 2 | .67 | .79 | 10.1 | .17 | .14 | .18 | .10 | .24 | .25 | .02 | .32 | .44* | .49* |

Note: Technology Proficiency Survey for Educators (TPSE), Synthesis of Qualitative Data (SQD) and Technology Pedagogy and Content Knowledge (TPACK)

RQ3, *To what extent do pre-service teachers display aligned patterns of technology self-efficacy, TPACK core and SQD over the period of a semester-long technology integration course?* at posttest there was no profile showing ambivalent scores in the different scales. At posttest a higher variance (almost 90%) was explained by function 1 which comprises a combination of different scales indicated that the different measures were working together (there is alignment) and *together* they discriminated between a high score and a low score. Moreover, the clusters' data at posttest showed a low dispersion from the mean value (standard deviation on all measures <.6), which highlights how not only the measures aligned in clearly defined and unique patterns (i.e., accomplished, cautious and medium), but consistency within each of these patterns.

The measures from the participants showed large gains from the beginning to the end of the semester in the skills and dispositions that were intended to be taught during the semester. The measures used in this study aligned to indicate the presence of many of the important aspects needed to support pre-service teachers in their pursuit of technology integration in the classroom. Student reflections at the end of the semester indicated they appreciated participating in this required course as it introduced them to technology supported content resources and tools they did not know existed while also guiding them to use these resources and tools to teach more effectively. Many of the students were in clinical teaching and reported the immediate use of what they learned in this course. In the reflective words of a pre-service student:

> *I have completely turned a 180 in relation to technology in my ELAR classroom! I will constantly be looking for ways to enhance my lessons with meaningful technology, check for understanding in ways that allow students to interact and create new programs, and assessments will be full of a variety of technological applications. I intend to seek out Technology in the ELAR classroom for professional development this summer!*

Implications for this type of study can guide educator preparation programs in assessing components they see as both important and required in the preparation of pre-service teachers. Measures that work together to form a broader picture of teacher candidates' strengths regarding technology integration can benefit a program. Because the measures are aimed at different components of technology integration, the use of these surveys can also aid in the identification of areas in a program that may need to be addressed. While these instruments were implemented as a pre-post design for a course, it is also possible to use these or other similar instruments to gather baseline measures to create a path for technology integration in a program. An interesting follow up study would be to follow these preservice teachers into their first years of teaching to see the impact of technology in their daily teaching.

## Ethical approval

The study was approved by University of North Texas IRB 21-414 and participants provided informed consent in the online system before completing the surveys.

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## Data availability

### Underlying data

Dataverse: Preservice Data for Technology Integration. https://doi.org/10.7910/DVN/JTA6NA (Christensen, 2022)

This project contains the following underlying data:

- DataCleanedForSharing_6semesters.xlsx (Anonymized participant data used for analysis are included in the spreadsheet.)

### Extended data

Dataverse: Preservice Data for Technology Integration. https://doi.org/10.7910/DVN/JTA6NA (Christensen, 2022)

The project contains the following extended data:

- SurveyitemAppendix.pdf

Data are available under the terms of the Creative Commons Zero "No rights reserved" data waiver (CC0 1.0 Public domain dedication).

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