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The Impact of a Teacher Education Program Redesign on Technology Integration in Elementary Preservice Teachers

Guy Trainin
University of Nebraska-Lincoln

Laurie Friedrich
University of Nebraska-Lincoln

Qizhen Deng
Boise State University

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by Guy Trainin, University of Nebraska-Lincoln; Laurie Friedrich, University of Nebraska-Lincoln; & Qizhen Deng, Boise State University

Abstract

This 5-year multicohort study examined the growth of elementary preservice teachers' technology integration in the context of a teacher preparation program redesign that made integrating technologies into instruction a major focus. The authors examined how the teacher education program impacted preservice teachers' technology integration in the classroom by increasing their efficacy to integrate technology and subject areas (i.e., technology, pedagogy, and content knowledge [TPACK] efficacy) and their technology knowledge. Survey data collected from 891 participants were analyzed using thematic coding, analyses of variance, and structural equation modeling. The full program redesign showed across-cohort growth in TPACK efficacy, technology knowledge, and technology integration frequency, suggesting the possibility of increasing preservice teachers' technology integration through redesigning the teacher education program. Findings indicated that modeling by teacher educators and cooperating teachers positively impacted TPACK efficacy, technology knowledge, and technology integration frequency. Technology knowledge predicted technology integration frequency. TPACK efficacy empowered preservice teachers with confidence to integrate technology but did not predict technology integration frequency. Implications for teacher education programs are discussed.

The recognition of the need for 21st-century student learning has spurred teacher education programs to purchase technology and adapt coursework to meet new demands from school districts and accreditation agencies (Bos, 2011; Male & Burden, 2014). Purchasing technologies for use without providing ongoing professional development for teacher educators and cooperating teachers has often resulted in little impact on the use of technology for teaching and learning (e.g., Hutchison, 2012; Tondeur, Pareja Roblin, van Braak, Voogt, & Prestridge, 2017).

Ball and Cohen (1999) set an ambitious agenda for teacher education, contending that to prepare teachers who move beyond the status quo teacher educators need to present a coherent and compelling vision. The challenge is to balance the reproductive nature of current classroom practice with knowledge and vision of 21st-century student learning.

For change to take place in technology integration, preservice teachers must be scaffolded to use technology effectively (Carpenter, Graziano, Borthwick, DeBacker, & Finsness, 2016; Wright & Wilson, 2005). In reality, not all preservice teachers observe state-of-the-art technology integration in method courses and field experiences; as a result, teacher education need a transformation to encourage meaningful integration by instructors and cooperating teachers (Ertmer & Ottenbreit-Leftwich, 2010; Martin, 2015; Tondeur et al., 2017).

The purpose of the multicohort study described here was to examine the growth of preservice teachers' technology integration in response to a teacher education program redesign that aimed to create a leading-edge technology integration experience as part of a 21st-century alignment. We also investigated how elements in the program were related to preservice teachers' technology knowledge, integration motivation, and classroom action.

The program redesign followed Ball and Cohen's (1999) suggestions to make sure that preservice teachers are positioned to be innovative and *future ready*. Building on the concept of laboratories of practice (Latta & Wunder, 2012), the program focused on understanding subject matter, learners, and pedagogy with technology as an integrated feature. The redesign was based on the framework of Technological, Pedagogical, and Content Knowledge (TPACK), following the recommendation by Darling-Hammond and Bransford (2005):

If teachers are to develop a curricular vision with respect to the use of technology for learning, teacher education programs need to think of their responsibilities as including the production of technically literate teaching professionals who have a set of ideas about how their students should be able to use technology within particular disciplines. (p. 199)

Theoretical Model

The theoretical model in Figure 1 conceptualizes the integration of the different elements that must come together to impact technology integration success and subsequent impact on K12 student achievement. The Teacher Education program impacts TPACK Efficacy and Technology Knowledge, two key components leading to successful educationally relevant technology integration. The term TPACK Efficacy refers to teachers' sense of efficacy about their ability to integrate technology and subject areas to teach meaningful lessons (one such item can be, "I can design lessons that combine literacy and technology effectively.").

Environmental Supports moderate any impact of the learning and motivation of preservice teachers to use technology in the classroom. Simply put, the availability of resources such as devices, reliable broadband connection, and technical support have a substantial impact on teacher's sustained engagement with technology, including cooperating teacher modeling of effective technology integration for preservice teachers (Chaliès, Bruno-Méard, Méard, & Bertone, 2010; Tondeur et al., 2017; Whittier, 2007). These cooperating teachers also need professional development to use the devices in student-centered ways, going beyond the assessment uses for which many are initially purchased (Sheninger & Murray, 2017; Walser, 2011).

The resulting instructional change should lead to K12 students' achievement, conceived broadly to include subject-specific knowledge, technology knowledge, and learning strategies. Following the logic expressed by Guskey (2002) implementation creates a feedback loop in which K12 student success further impacts TPACK Efficacy and Technology Knowledge. When preservice teachers, teacher education faculty, and cooperating teachers all integrate technology as both a teaching and learning tool, teacher education programs impact schools and K12 students in positive ways.

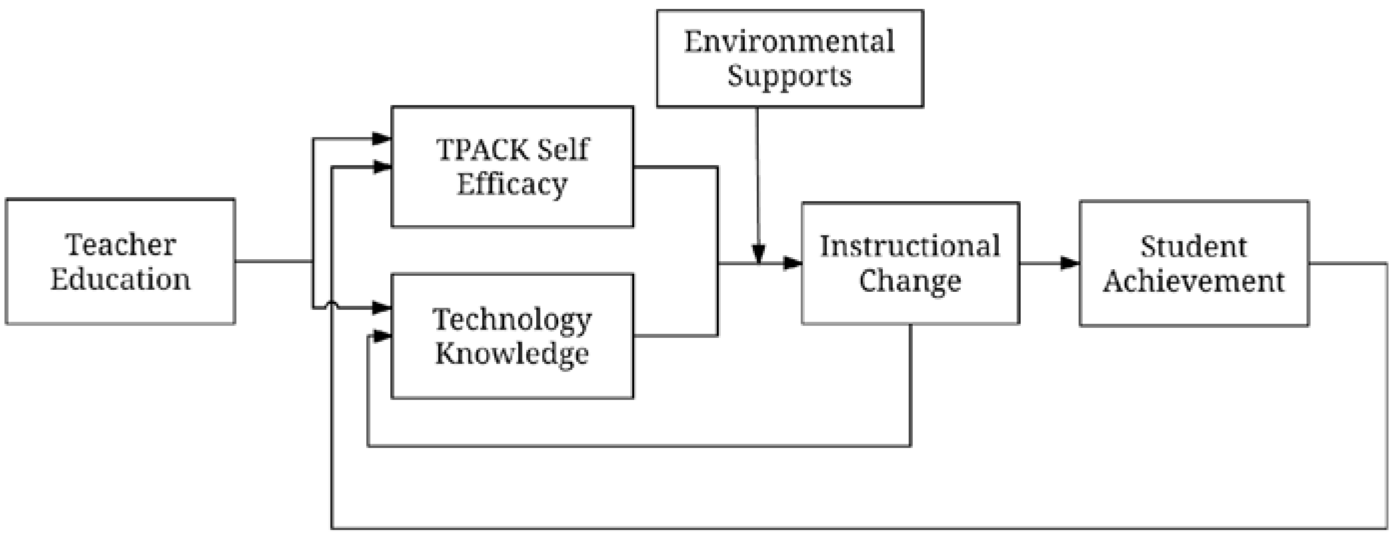

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Figure 1. *Theoretical model for effective teacher education impacting technology integration.*

Literature Review

TPACK

TPACK builds on Shulman's (1986) pedagogical content knowledge framework. Shulman argued that the most effective teaching takes place when teachers merge their understanding of content and pedagogy to plan learning experiences that overcome teaching challenges. TPACK refers to "an emergent form of knowledge that goes beyond all three components (content, pedagogy, and technology)" (Mishra & Koehler, 2006, p. 1028). It is an understanding that emerges from the interaction of these bodies of knowledge, both theoretically and in practice, producing flexible knowledge necessary to successfully integrate technology into teaching (Carpenter, et al., 2016; Koehler & Mishra, 2009). Teachers need to understand "not just the subject matter they teach, but also the manner in which the subject matter can be changed by the application of technology" (Mishra & Koehler, 2006, p.1028).

These three components are more than the sum of their parts, empowering teachers to facilitate lessons where technology advances student learning to a new level. As devices and uses for technology in schools increase, the TPACK framework adds a technological knowledge component highlighting the need for teachers to know how technology can influence content and pedagogy.

The TPACK framework has become ubiquitous in the educational technology field and is supported by the American Association of Colleges for Teacher Education (AACTE; Carpenter, et al., 2016). The existing literature on this topic has come from work with both established teachers (e.g., Bruce & Chiu, 2015; Graham et al., 2009; Harris & Hofer, 2017) and preservice teachers (e.g., Niess, 2008).

At the same time, AACTE has embraced the TPACK model for preservice teachers so they learn how and why to integrate technology as they begin planning and teaching (Herring, Koehler, & Mishra, 2016). With constantly evolving technologies, teacher education must prepare preservice teachers to teach in ways that prepare students to learn using these digital tools (Niess, 2008).

TPACK as a Basis for Program Redesign

As researchers have begun to focus on techniques to aid TPACK growth in preservice and in-service teachers (e.g., Cavin, 2008; Graham et al., 2009), modifications in courses and fieldwork are emerging (Koehler et al., 2012). Our program redesign began with the three primary foci for developing TPACK in teacher preparation programs, as outlined by Hofer and Grandgenett (2012): "a dedicated educational technology course; content-specific teaching methods, or practicum courses; or through the duration of coursework in a teacher preparation program" (p. 87). We changed the "or" to "and," however, to layer opportunities and capacity.

Empirical studies on developing TPACK had mainly focused on one or two of these components. For example, Chai, Koh, and Tsai (2010) focused on the first component by teaching TPACK in an educational technology course with a cohort of 889 preservice teachers in a postgraduate secondary education program in Singapore. The technology course focused on pedagogical and technological knowledge. The instructors presented a technology tool and its pedagogical use to students organized by subject area, who created a final thematic unit comprised of technology enhanced lessons in their area. Findings showed that technology courses that directly taught technology tools along with pedagogy raised preservice teachers' technological and pedagogical knowledge with moderate to large effect sizes.

Similarly, Maor (2017) conducted a study of two consecutive versions of a mainly graduate technology course in Australia using blended learning for instructors to model, and students participated collaboratively with technology to explore the effect of TPACK on digital pedagogies. Maor found significant TPACK growth in each domain, along with greater confidence and understanding of TPACK application, leading to implementation in the classroom.

Harris and Hofer (2011) utilized content-specific teaching methods (second component) for professional development to help teachers go beyond self-evaluating TPACK to put *TPACK-in-Action*. Seven classroom teachers participated in the study of TPACK professional development. The instructor presented examples, descriptions, and suggested technologies to accomplish curriculum goals. Participants then planned a unit by incorporating a variety of learning activities into the content and pedagogy. Teachers noted that adding selected activities and technologies allowed them to effect deeper, more self-directed learning in the classroom. Five of the seven teachers commented on how the activities facilitated the fit between the TPACK domains, teaching requirements, and time.

Mouza, Karchmer-Klein, Nadakumar, Yilmaz Ozdem, and Hu (2014) combined the first two components for building TPACK in teacher education. They built on the idea that, when the technology course is integrated with method courses and field experience, preservice teachers benefit by applying learning directly into teaching with technology (Niess, 2005, 2012). Their study examined 88 preservice teachers enrolled in the technology course and related method courses during one semester. All preservice teachers showed significant growth in each TPACK area and applied their knowledge during field experience. However, Mouza et al. noted that it was difficult to place preservice teachers in classrooms where teachers effectively modeled technology integration. Cooperating teachers used technology for teaching and learning in a very limited way, so preservice teachers mainly learned pedagogy (PCK and pedagogical knowledge), not technology integration, from cooperating teachers.

Hofer and Grandgenett (2012) added the third component of technology integration throughout a program as they examined TPACK integration through a three semester graduate teaching program with eight participants. Results indicated growth in TPACK throughout the program, but the largest gains occurred when preservice teachers were concurrently enrolled in the educational technology course and their first method course, where they discussed teaching strategies, lesson planning, and technology integration.

Preservice teachers' TPACK in lesson plans fell slightly during student teaching, and the authors suggested that the demands of classroom practice may have negatively impacted technology integration. Hofer and Grandgenett (2012) suggested a need for more longitudinal studies of TPACK across teacher education programs.

Current research demonstrates that the three TPACK components are being used successfully in teacher preparation programs; however, they also indicate the need for further investigations focusing on sustainable longitudinal program wide approaches. The current study included all three components (technology course, technology infused into method courses, field experiences, and across program) integrated into consecutive iterations.

The Role of Teacher Efficacy

Ertmer and Ottenbriet-Leftwich (2010) suggested that to change and sustain teachers' technology practices teacher educators need to focus on knowledge, self-efficacy, pedagogical beliefs, and culture in both teacher education programs and teacher professional development. Research on motivation emphasizes the role beliefs play in influencing persistence, behaviors, and achievement.

The motivational construct of *self-efficacy* (Bandura, 1986) has become the focus of educational research in varied domains, such as mathematics, science, reading, writing, and sports (Bandura, 1997; Pajares, 1997; Pajares & Miller, 1994; Schunk & Zimmerman, 2007). Self-efficacy is a person's estimation of the probability of success if they attempt to organize and execute actions required to accomplish a task (Bandura, 1986). In education, self-efficacy has been shown to be a powerful predictor of students' motivation and academic achievement (e.g., see Schunk & Pajares, 2009).

Teacher self-efficacy refers to teacher's beliefs about their capacity to accomplish pedagogical tasks (Bandura, 1986). It is the basis for understanding teachers' beliefs about their ability to translate their knowledge into successful action. For example, Abbitt (2011) found that teacher efficacy for technology integration interacted with TPACK in predicting change in technology integration.

Teacher efficacy is crucial in making sure that the capacity teachers acquire will actually be used in the classroom. As illustrated in Figure 1, successful implementation of educational change, in our case technology integration, requires the confluence of knowledge, motivation, and resources. TPACK alone may not translate into sustained integration into teaching and student learning without teachers believing they can do it (Bauer & Kenton, 2005; Ertmer & Ottenbreit-Leftwich, 2010; Corkin, Ekmekci, White & Fisher, 2016; Wozney, Venkatesh, & Abrami, 2006).

Teachers and preservice teachers need multiple experiences integrating technology in classrooms and practicum situations to build confidence through personal mastery and vicarious learning, the strongest sources of self-efficacy (Bandura, 1997).

The Role of Modeling

Preservice teachers have been learning from their own teachers throughout their K12 schooling in a process Lortie (1975) called "the apprenticeship of observation." However, as students, they do not always have access to the knowledge, skills, and reasoning behind the myriad of procedures they observe, sometimes causing misconceptions about teaching. Modeling, on the other hand, is a high leverage activity that can scaffold vicarious learning into personal mastery when teacher educators and teachers share their thought processes to support actions and move preservice teachers into the role of teacher (Grossman, Hammerness, & McDonald, 2009).

Ertmer (2003) found that when teacher educators, cooperating teachers, and preservice teachers collaborate to plan technology integrated lessons, modeling happens naturally as teachers each demonstrate their area of expertise. Ertmer further noted that some teacher education programs explicitly model what a meaningful technology integrated lesson looks like before preservice teachers try to create lessons themselves. In such ways, teachers at all levels tend to benefit from observing a variety of expert performance as they move toward more advanced levels of technology use.

Baran, Canbazoglu Bilici, Albayrak Sari, and Tondeur (2017) showed that instructor modeling in three teacher education programs in Turkey was a significant predictor of

TPACK perception by preservice teachers. Angeli (2005) used explicit modeling by teacher educators to explain and demonstrate their process of integrating lessons with technology to prepare preservice teachers. After building confidence by observing an expert, preservice teachers created their own technology integrated science lessons for elementary students, guided by teacher educators. Findings showed that along with modeling teacher educators also need to explain the pedagogical reasoning so preservice teachers see "how the teacher's role changes, how the subject matter gets transformed, and how the learning process is enhanced (Angeli, 2005, p. 395). What's more, teacher educators should explicitly teach how to apply the unique features of a tool to transform a specific content domain in ways not possible without the tool.

Summary

In order to create meaningful change in the ways teachers use technology in their classroom, knowledge and self-efficacy have to be purposefully attended to, while making sure that resources are available so technology can be used. To move the field forward, all stakeholders in a teacher education program need to move together. University faculty need to model effective use of technology in courses and empower preservice teachers to utilize these tools in coursework and beyond. Cooperating teachers need professional development adding technology into instruction as personal digital devices become ubiquitous in education.

The model presented in Figure 1 was the basis of the redesign in our teacher education program. We progressively added components that supported all aspects of TPACK efficacy, technology knowledge, and resources to create optimal conditions for developing teachers ready to teach in the 21st century.

We focused on three questions:

1. How do preservice teachers' TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency change over time in response to integration of

technology practices into the teacher education program?
2. What is the contribution of TPACK Efficacy and Technology Knowledge to Technology Integration Frequency in the classroom?
3. What is the impact of modeling on TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency?

Methods

Participants

The participants were 891 preservice teachers (801 female, 90%) from 11 cohorts across consecutive semesters ($n_1 = 92$, $n_2 = 75$, $n_3 = 82$, $n_4 = 82$, $n_5 = 81$, $n_6 = 83$, $n_7 = 80$, $n_8 = 65$, $n_9 = 107$, $n_{10} = 64$, $n_{11} = 80$) from fall 2011 to fall 2016 in a large Midwestern university. All participants were undergraduate students. Most were traditional students aged between 19 and 25 ($n = 846$; 95%), in addition to 24 students aged between 26 and 30 (3%), and 21 students between 31 and 50 (2%). They were enrolled in an elementary education program, with 58% focusing on elementary-only, 24% on elementary special education, 12% on inclusive P-3 education, 5% on early elementary education, and 1% on elementary and English learners. The majority of the participants were Caucasian ($n = 864$, 97%), with some Hispanic ($n = 13$), African American ($n = 9$), and Asian American ($n = 5$). At the time the data was collected, the participants were at the end of student teaching their final semester.

Measures

An online survey was administered to all student teachers in their last semester in the program (student teaching; see Appendix). After responding to demographic questions, preservice teachers were introduced to three instruments.

Technology Knowledge. The first instrument measured their Technology Knowledge adapted from the Survey of Preservice Teachers' Knowledge of Teaching and Technology

(Schmidt et al., 2009). There were seven items in Technology Knowledge on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). We adapted six items and replaced one item with the reported lowest factor loading (.65) – "I have had sufficient opportunities to work with different technologies" – with "Colleagues often ask me to help them with technology," developed by the researchers. This item focused on preservice teachers' mastery experience working with technology and was validated with technology coaches from across the state. The reliability of the seven items in this study was .88 using Cronbach's alpha, slightly higher than the value .82 reported previously (Schmidt et al., 2009).

TPACK Efficacy. The second instrument included (a) measurement of preservice teachers' TPACK Efficacy in designing and teaching lessons that combine subject matter and technology to reach objectives (adapted from Schmidt et al.'s TPACK knowledge domain, 2009) on a Likert scale from 1 (*highly ineffectively*) to 5 (*highly effectively*), (b) the frequency of such lessons on a Likert scale from 1(*never*) to 4 (*in all of my classes*), and (c) three open-ended questions soliciting preservice teachers' detailed description of a lesson in which they integrated content and technology effectively to reach their lesson objectives:

1. What was the content?
2. What technology did you use? What did you use it for?
3. What technology did students use? What did they use it for?"

For TPACK Efficacy, we adapted only four items measuring preservice teachers' efficacy to integrate subject areas relevant to our teacher education program of interest: literacy, mathematics, science, and social studies. The reliability was .87 for the adapted four items, compared to the original scale with a reliability of .92 for nine items (Schmidt et al., 2009).

Modeling. The third instrument focused on modeling adapted from Schmidt et al.'s (2009) measure of Models of TPACK (faculty, PK-6 teachers). Preservice teachers were first asked to name one individual who was an exceptional model in technology integration and describe her/his role. Following were seven items asking preservice teachers to rate whether university classes have modeled technology integration effectively (i.e., Literacy Methods, Mathematics Methods, Science Methods, Social Studies Methods, Technology Methods, Practicum/Student Teaching, and Reading Center) on a Likert scale from 1 (*highly ineffectively*) to 5 (*highly effectively*). We adapted the six items from Schmidt et al. (2009). In addition, we added one item to address the modeling at the Reading Center that is an integral part of our teacher education program. The reliability for these items in this study was .57. Schmidt et al. (2009) did not provide reliability for the items measuring modeling.

Data Analysis Procedures

Our first research question focused on how preservice teachers' TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency changed across cohorts. To achieve this goal, we used one-way ANOVAs to determine any differences in preservice teachers' reported scores across cohorts. Before conducting ANOVAs, we administered Chi-square tests to examine the characteristics of participants across cohorts regarding their gender, age, and program focus. Participants' age was categorized into three groups (from 19 to 25; 26 to 30; and 31 to 50). Initial analysis also examined potential outliers and the normality and homogeneity of measured variables. We used the mean of items to calculate Technology Knowledge; therefore, Cronbach's alpha was computed to examine its internal consistency.

For the second and third research questions, we applied structural equation modeling (SEM) to examine the relationships among teacher program Modeling, TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency. SEM is a statistical technique that models the relationships among latent factors. We applied a two-step process: (a) a confirmatory factor analysis (CFA) to confirm that the measurement model fit respective data; and (b) a structural regression model to examine the relationships among latent factors (Thompson, 2000).

Additionally, for Questions 2 and 3 we analyzed narrative data from the open-ended questions in the survey using Miles and Huberman's (1994) thematic coding. After reading through all data to get a sense of the content, we reread using open coding, assigning codes created initially as well as adding axial codes as needed. We then read the data a third time looking for patterns and answers to research questions. Rich and thick quotes (Creswell, 1998) were selected to express how preservice teachers explained actual lessons they taught integrating technology as well as how their best teaching models integrated technology.

Program Development

Over a period of 5 years the teacher education program was redesigned to strengthen preservice teachers' TPACK (Trainin & Friedrich, 2014; Trainin, Friedrich, & Deng, 2013). Each component built upon the five elements of professional development, which Desimone (2009) has shown to be effective: focused content, collective participation, active learning, duration, and coherence.

In addition, Dagen and Bean (2014) noted a new wave of research emphasizing collaborative learning as a key feature, taking into consideration the teacher's organization. They maintained that "effective professional development would encompass as many of those features as appropriate for a specific professional development initiative" (p. 47). We discuss each component of the transformed teacher education program in relation to these core features of effective professional development (see Figure 2).

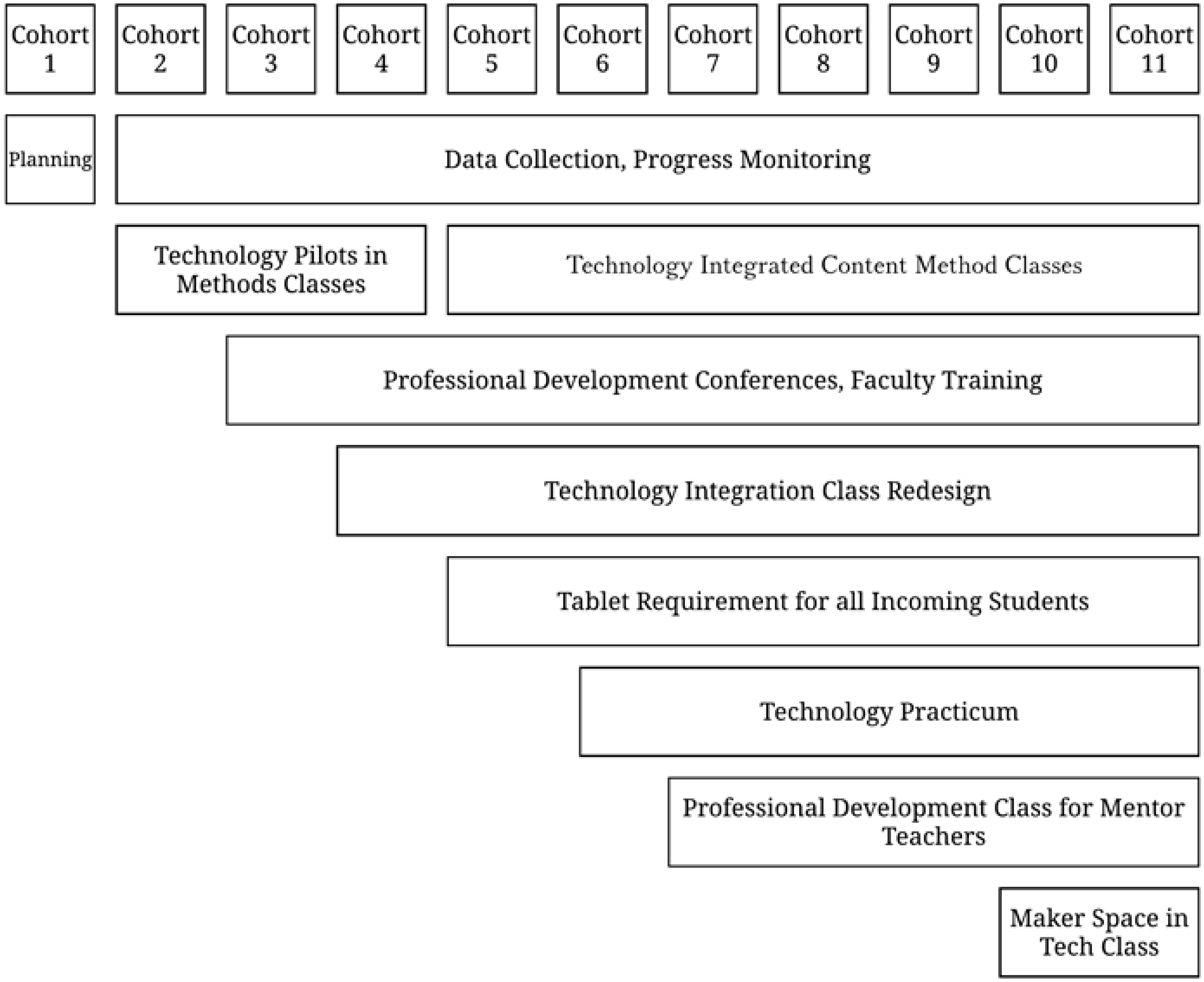

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Figure 2. *Teacher education program redesign components as rolled out throughout cohort.*

Technology Integration Planning and Baseline Data Collection. The transformation began with a University Reading Center pilot, where we had full control over devices and apps, one-to-one usage with students, and supervision to allow teacher educators to model in class and preservice teachers to enact TPACK in real time. The course content focused on strategies to assist striving readers and writers and was designed to engage preservice teachers in collaborative learning to plan lessons and share student results.

At the same time the pilot was enacted we collected baseline data from the preservice teachers who were then in student teaching. Cohort 1 completed the adapted Survey of Preservice Teachers' TPACK to provide a baseline measure of TPACK Efficacy to plan and teach TPACK lessons, as well as frequency of actual implementation, technology knowledge, and effectiveness of teacher educators in modeling technology integration. Each cohort following completed the same survey during student teaching.

Technology Pilots in Method Classes. The literacy methods course demonstrated the technology fit into content and pedagogy (TPACK) as iPads were integrated into teaching and learning. Preservice teacher use of a class set of Version 1 iPads, cameras, and software began the methods course redesign. Instructors modeled a variety of apps and discussed uses to teach literacy components, which preservice teachers then used to teach elementary students in the associated practicum. The program built upon this learning to integrate the technology component to focused content in mathematics, science, and social studies method courses in progressive semesters using an active learning format, where preservice teachers observed and participated in class then taught in practicum.

Professional Development Conferences. One professional development conference per semester offered preservice teachers, cooperating teachers, and teacher educators opportunities to learn and collaborate around technology. The goal of the conferences was to help all three teacher groups develop as professionals integrating technology through collective participation with each other. The program required preservice teachers and encouraged cooperating teachers and teacher educators to attend university-planned conferences that provided hands-on technology practice through active learning using real classroom examples shared by peers from all groups.

The conferences assisted cooperating teachers in integrating technology in meaningful ways to assist their schools and to provide locations where preservice teachers could experience effective integration in action. Wepner et al. (2012) found that school-university partnerships can expose teachers to new methodologies, provide innovative and cutting-edge ideas for the classroom, encourage collaborative inquiry about practice, renew the love of teaching, and develop teacher leadership. Building upon collaborative partnerships with the local school districts, all teachers were invited to attend the professional development conferences along with the preservice teachers. As we observed teachers grow in technology integration, we invited them to present at upcoming professional development conferences.

The format of the conference frequently began with a keynote that challenged participants to consider emerging issues in education including 1:1 technology integration in classrooms, innovative learning spaces, classrooms of the future, makerspaces, and project-based learning STEAM (science, technology, engineering, art, and mathematics) curriculum. Participants then attended self-selected sectionals to meet individual goals.

For example, an elementary teacher modeled how she used Green Screen technology to empower students to make videos to demonstrate learning about systems of the human body. This presenter modeled the process and showed student sample projects before inviting participants to collaborate with a partner to create a video during the sectional.

Although the conference lasted one day, the duration of the learning continued as preservice teachers collaborated throughout the semester with cooperating teachers, peers, and supervisors (Friedrich & Trainin, 2016). A prototypical 5-hour conference offered fifteen 45-minute sessions plus a keynote. Classroom teachers presented 11 sessions with university instructors and State Department of Education personnel presenting two sessions each. All sessions utilized a bring-your-own-device hands-on format.

Faculty Training. Parallel to the professional development conferences, Teacher Educators received ongoing professional development through the redesigned program. Instructors were invited to attend monthly collaborative learning meetings, where all attending shared new tools and uses and answered questions. A university-focused professional development conference each summer challenged teacher educators to innovate teaching methods and share their learning with other teacher educators from across the state.

Sectionals supported instructor needs ranging from novice to expert (e.g., online teaching and feedback, mobile devices in the classroom, collaborating, Google tools for teacher productivity and student learning, and update on technology integration at the elementary, secondary, and university levels). Through collective participation in an active learning format, instructors encountered tools and strategies used in their content focus area.

Technology Integration Class Redesign. The technology integration course was reimagined to fit the new vision for preservice teachers. The first step was to fix the timing of the class to the beginning of the professional program. In this way preservice teachers were gaining pedagogical knowledge with the accompanying technological and integrated skills that could be used over the duration of the program. The curriculum was changed to build on the availability of mobile devices and eventually district one-to-one integration. The course itself was split so that later in the program we could add a practicum in technology integration during literacy methods and practicum.

Tablet Requirement. The redesigned program required preservice teachers to have a tablet for entrance into the teacher education program. This intentional decision provided environmental support assuring that each preservice teacher had equal access to technology for teaching when schools and cooperating teachers differed in their access to and uses of technology. The college supported purchase for students with financial difficulty. Device availability in class and practicum allowed full participation in courses that were redesigned for learning in and through technology.

Technology Practicum. Preservice teachers engaged in a technology practicum during literacy methods semester. The program provided coaching by university supervisors in practicum classrooms as a model of technology integration, an environmental support to sustain instructional change by scaffolding meaningful technology integration by preservice teacher/cooperating teacher teams. When appropriate, these coaches suggested learning activities where technology could allow K-5 students to learn using digital sources in addition to print sources and, when needed, assisted with teaching lessons that involved using technology to teach and learn.

Professional Development Class for Cooperating Teachers. The program offered a parallel course for interested cooperating teachers to learn the same uses for technology in the classroom that their preservice teacher was learning in technology practicum. This course supported cooperating teachers as they explored tools and designed lessons, implementing in their classroom with their preservice teacher supported by a university coach.

Makerspace. The program continues to add components in an effort to prepare preservice teachers for the rapidly emerging technologies and pedagogies entering schools. The most recent addition is a Makerspace component integrated into the technology integration class. Effective technology integration today empowers students as creators using technology, and the Makerspace is an effort to make sure that all preservice teachers have the capacity to engage with making (Sheninger & Murray, 2017). Learning in a supportive environment where trial and error is encouraged, preservice teachers ask questions and create projects to solve real problems.

Results

Before answering the research questions, we conducted initial analyses to examine whether assumptions for multivariate analyses were met. Test of Normality with Kolmogorov-Smirnov indicated violation of normality for preservice teachers' TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency. We also referred to Q-Q plots inspection, and skewness (ranged from -1.11 to .57) and kurtosis (ranged from -1.27 to 1.35), which indicated reasonable normality for all variables. The homogeneity of variance assumption was met for all variables in TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency ($p > .05$). We examined the need for covariates and demographic factors, which revealed no significant difference across cohorts in preservice teachers' gender, $c^2(10, 891) = 3.11$, $p = .927$; age, $c^2(20, 891) = 22.63$, $p = .066$, and program focus, $c^2(40,891) = 38.16$, $p = .10$.

Growth

TPACK Efficacy. Four separate one-way ANOVAs were conducted to examine any differences across cohorts in preservice teachers' TPACK Efficacy in four content areas, including literacy, mathematics, science, and social studies. The results suggested significant differences across cohorts for technology integration with literacy, $F(10,881) = 73.08$, $p < .001$; mathematics, $F(10,881) = 53.59$, $p < .001$; science, $F(10,881) = 33.87$, $p < .001$; and social studies, $F(10,881) = 35.25$, $p < .001$. Detailed descriptive statistics are presented in Table 1.

Table 1

Means and Standard Deviations by Cohort Number for TPACK Efficacy Subject Areas and Technology Knowledge

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	***d3* (11 to 1)**
TE in Literacy	1.79 (.74)	3.95 (.87)	3.94 (.87)	4.00 (.88)	4.00 (.87)	4.11 (.76)	4.31 (.69)	4.29 (.67)	4.07 (.93)	4.13 (.97)	4.15 (.78)	3.10
TE in Math	1.75 (.62)	3.91 (1.02)	3.90 (1.02)	4.04 (.97)	4.00 (.92)	4.05 (.89)	4.13 (.80)	4.09 (.81)	3.87 (1.06)	3.84 (1.08)	4.05 (.91)	2.95
TE in Science	2.11 (.89)	3.74 (.86)	3.74 (.86)	3.70 (.96)	3.86 (.92)	3.96 (.78)	3.92 (.81)	3.92 (.79)	3.75 (.98)	3.52 (1.00)	3.95 (.85)	2.11
TE in Social Studies	2.04 (.98)	3.71 (.91)	3.72 (.89)	3.79 (.97)	3.76 (.89)	3.96 (.82)	3.87 (.80)	3.88 (.78)	3.75 (.98)	3.69 (1.08)	3.96 (.86)	2.08
TK	3.94 (.80)	3.52 (.68)	3.85 (.65)	3.85 (.51)	3.82 (.62)	3.84 (.55)	3.82 (.47)	3.93 (.58)	3.87 (.60)	3.84 (.49)	4.07 (.48)	

Notes: TE = TPACK Efficacy, TK = Technology Knowledge. 5-point scale; For TE, 1 = *Strongly Disagree*; 2 = *Disagree*; 3 = *Neither Agree Nor Disagree*; 4 = Agree; 5 = *Strongly Agree*. For TK, 1 = *Highly Ineffectively*; 2 = *Somewhat Ineffectively*; 3 = *Neutral*; 4 = *Somewhat Effectively*; 5 = *Highly Effectively.*

We conducted follow-up procedures with a Tukey HSD post hoc test to compare differences among cohorts. The findings revealed incremental improvement that became significant over multiple cohorts. For example, Technology Integration Frequency for literacy in Cohort 1 was significantly lower than that in all other cohorts ($p < .001$ for all comparisons). Technology Integration Frequency for literacy in Cohort 2 ($M = 2.10$; $SD = .64$) was significantly lower than that in most following cohorts; for example, Cohort 7 ($M = 2.44$; $SD = .71$; $p = 04$) and Cohort 9 ($M = 2.63$; $SD = .71$; $p < .001$).

For mathematics, Technology Integration Frequency in Cohort 1 was significantly lower than Cohort 2 ($p = .031$) and the rest of cohorts ($p < .001$ for all comparison). Technology Integration Frequency in Cohort 2 was significantly lower than that in Cohort 9 and beyond. For science, Technology Integration Frequency in Cohort 1 was significantly lower than in Cohort 3 ($p = .008$), Cohort 6 ($p = .011$), and all subsequent cohorts.

For social studies, Technology Integration Frequency in Cohort 1 was significantly lower than in Cohort 2 ($p = .022$), cohort 3 ($p < .001$), and beyond. Technology Integration Frequency in Cohort 2 ($M = 1.94$, $SD = .64$) was significantly lower than that in Cohort 11 ($M = 2.22$, $SD = .71$, $p = .002$). Technology Integration Frequency in Cohort 5 ($M = 1.90$, $SD = .64$) was significantly lower than that in Cohort 10 ($M = 2.27$, $SD = .72$; $p = .047$) and Cohort 11($M = 2.22$, $SD = .71$; $p < .001$). Last, Cohort 8 ($M = 1.92$, $SD = .69$) was significantly lower than Cohort 11 ($M = 2.22$, $SD = .71$; $p = .001$). The change in social studies appears to have been more incremental than other domains.

Overall, the effect sizes (Cohen's *d*; Cohen, 1969) for the Technology Integration Frequency differences between Cohort 1 and Cohort 11 were large, with the values ranging from .90 to 1.72 (see Table 2), indicating that preservice teachers in Cohort 11 integrated technology more frequently in all four subject areas than those at baseline.

Table 2

Means and Standard Deviations for the Frequency for Technology Integration by Subject Areas

	Cohort											**Cohen's *d***		
Subject Areas	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**3 to 1**	**11 to 8**	**11 to 1**
Literacy	1.61 (.60)	2.10 (.64)	2.36 (.61)	2.36 (.62)	2.23 (.63)	2.41 (.56)	2.44 (.71)	2.42 (.71)	2.63 (.71)	2.81 (.71)	2.71 (.68)	1.24	.42	1.72
Math	1.75 (.71)	2.14 (.60)	2.49 (.79)	2.47 (.70)	2.41 (.77)	2.34 (.72)	2.40 (.86)	2.37 (.86)	2.52 (.76)	2.59 (.81)	2.63 (.82)	.99	.31	1.15
Science	1.65 (.63)	1.94 (.76)	2.06 (.71)	2.07 (.72)	1.95 (.77)	2.05 (.76)	2.06 (.69)	2.06 (.68)	2.24 (.76)	2.11 (.69)	2.29 (.78)	.61	.76	.90
Social Studies	1.57 (.65)	1.94 (.64)	2.07 (.73)	2.11 (.68)	1.90 (.64)	2.20 (.70)	1.94 (.69)	1.92 (.69)	2.22 (.71)	2.27 (.72)	2.40 (.77)	.72	.66	1.16

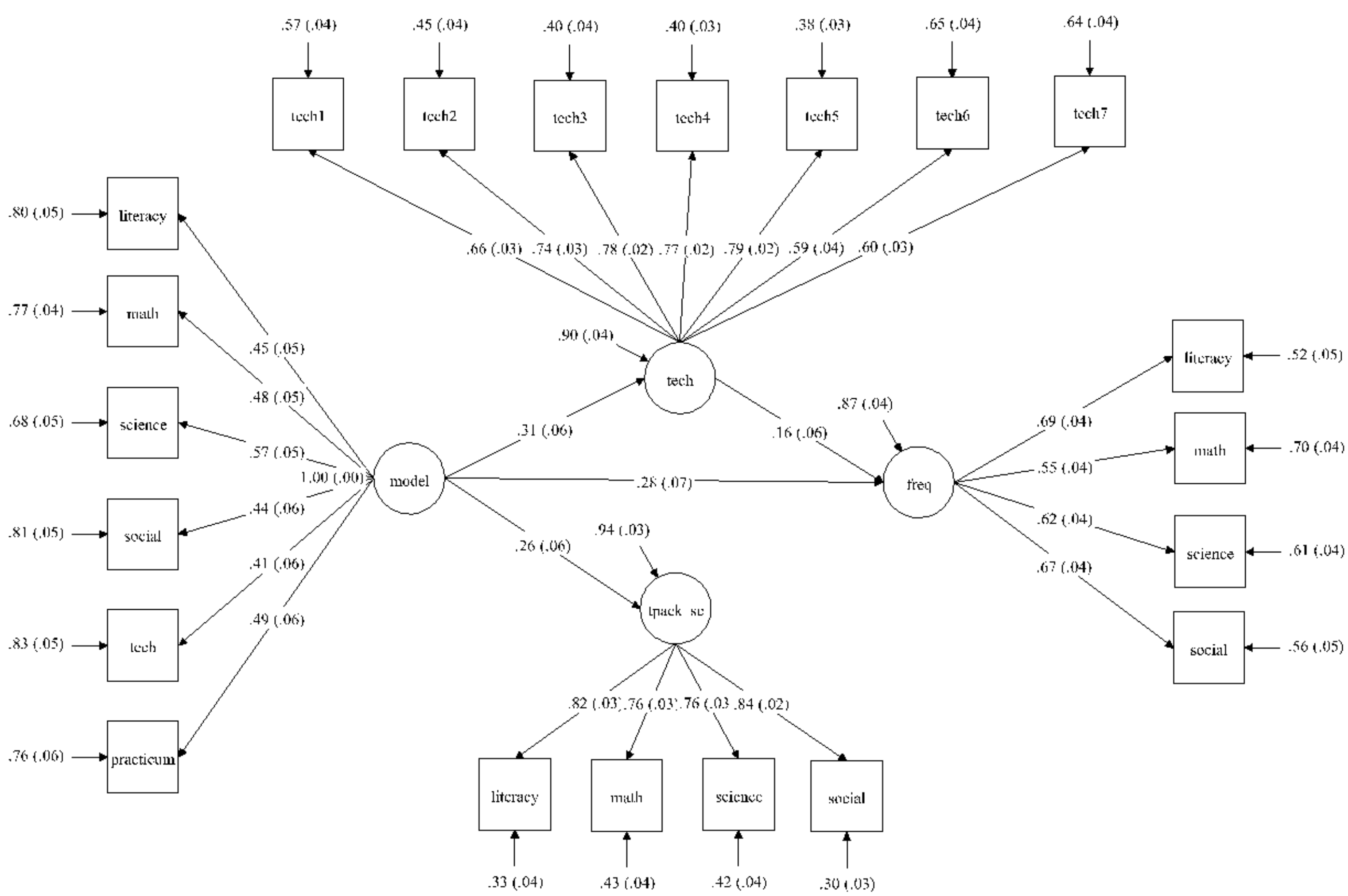
Notes. 4-point Scale; 1 = *Never*; 2 = *in a few lessons*; 3 = *in most lessons*; 4 = *in all of my lessons.*

Interestingly, the data showed two waves of increase in Technology Integration Frequency for all four content areas (see Table 2 and Figure 3). The first increase happened between Cohort 1 and Cohort 3, with the effect sizes ranging from .61 to 1.24. In Cohort 1, preservice teachers reported they had integrated technology in very few lessons for all four subject areas. In Cohort 3, preservice teachers reported they had integrated technology in some lessons for literacy and mathematics and a few lessons for science and social studies. Preservice teachers' Technology Integration Frequency did not change significantly between Cohort 3 and Cohort 8.

The second increase happened between Cohort 8 and Cohort 11, with the effect sizes ranging from .31 to .76. In Cohort 11, preservice teachers reported that they had integrated technology in most lessons in literacy and mathematics and in some lessons in science and social studies. Narrative responses describing a lesson in which preservice teachers effectively integrated content and technology matched preservice teachers' self-efficacy ratings for integrating technology into these content areas, as well as their frequency of integrating technology in lessons in these areas. Preservice teachers most frequently described a literacy or math lesson, with science and social studies being mentioned less.

Relationships

To answer the second and third research questions, we used a structural equation model (Kline, 2011) to test the fit of the conceptualized theoretical model to the data. The model was tested using the robust maximum likelihood estimator (MLR) with standard errors that are robust to nonnormality. The criteria for model fit included model χ^2, the comparative fit index (CFI: values above .95 indicate good fit, and at or above .90 indicate reasonable fit; Bentler, 1990), RMSEA (values lower than .06 are desirable for good fit; Steiger, 1990), and SRMR (values lower than .08 are considered a good fit; Hu & Bentler, 1999). The use of multiple fit indexes is recommended to evaluate the fit of a model with a more holistic view (Kline, 2011). Figure 4 presents parameters from the measurement model and structural model.



[https://citejournal.s3.amazonaws.com/wp-content/uploads/v18i4general1Fig4.png]

Figure 4. *Results for the Structural Equation Model. Boldface arrows indicate the structural component between model (i.e., Modeling), tpack_se (i.e, TPACK Efficacy), freq (i.e.,*

Technology Integration Frequency), and tech (i.e., Technology Knowledge).

Measurement Model. The latent factor of Modeling has six manifest variables describing university classes modeling technology integration effectively (Cronbach's alpha = .64). The latent factor of TPACK Efficacy has four manifest variables, including preservice teachers' efficacy to integrate technology and subject areas (i.e., literacy, mathematics, science, and social studies) to reach lesson objectives (Cronbach's alpha = .87). The latent factor of Technology Knowledge was represented by eight manifest variables (Cronbach's alpha = .73). Last, the latent factor of Technology Integration Frequency includes four manifest variables, including preservice teachers' frequency of technology integration in literacy, mathematics, science, and social studies (Cronbach's alpha = .71).

All manifest variables loaded significantly onto their respective latent factors ($p < .001$ for all standardized coefficient estimates; see Figure 4). The standardized coefficients ranged from .41 to .57 for Modeling, from .76 to .84 for TPACK Efficacy, from .53 to .79 for Technology Knowledge, and from .55 to .67 for Technology Integration Frequency. The overall model fit was good. The chi-square was statistically significant, $\chi^2(200) = 551.15$, $p < .001$, but other fit indices were in the expected range: CFI = .923, TLI = .911, RMSEA = .05 (90% CI = .047, .058), and SRMR = .047.

There was significant correlation between Modeling and Technology Knowledge ($r = .30$, $p < .001$), Modeling and TPACK Efficacy ($r = .25$, $p < .001$), Modeling and Technology Integration Frequency ($r = .33$, $p < .001$), TPACK Efficacy and Technology knowledge ($r = .13$, $p = .028$), and TPACK Efficacy and Technology Integration Frequency ($r = .25$, $p < .001$). The correlation was not significant between TPACK Efficacy and Technology Integration Frequency ($r = .09$, $p = .194$).

Structural Model. A structural model with all latent factors and their respective predictors were tested. Figure 4 presents the results with significant path in solid line. The chi-square was statistically significant, $\chi^2(202) = 568.58$, $p < .001$, CFI = .920, TLI = .908, RMSEA = .053 (90% CI = .050, .059), and SRMR = .053. We compared this model to an alternative following modification suggestion, where we added the path between modeling and technology integration. An adjusted chi-square difference test yielded a significantly better fit of the alternative model, $\Delta\chi 2(1, N = 891) = 15.32$, $p < .001$. Therefore, the alternative model was the final structural model (see Figure 4).

Standardized path coefficient values are presented along the path. The chi-square was statistically significant, $\chi^2(201) = 551.64$, $p < .001$, but the model fit was good according to other indices, CFI = .923, TLI = .912, RMSEA = .052 (90% CI = .047, .057), and SRMR = .048. The significant chi-square statistic might be due to the large sample size in the study, as chi-square statistic is sensitive to sample size and model complexity (Hu & Bentler, 1999).

Research Question 2 focused on the contribution of TPACK Efficacy and Technology Knowledge to Technology Integration Frequency in the classroom. Technology Knowledge significantly predicted preservice teachers' Technology Integration Frequency in the classroom. However, preservice teachers' TPACK Efficacy did not significantly predict their Technology Integration Frequency. The results suggested that Technology Knowledge contributed to preservice teachers' technology integration in classroom instruction; TPACK Efficacy, however, did not contribute to their technology integration.

Research Question 3 examined the impact of teacher program Modeling on Technology Knowledge, TPACK Efficacy, and Technology Integration Frequency. Modeling significantly predicted preservice teachers' TPACK Efficacy, Technology Knowledge, and Technology Integration Frequency, indicating that the modeling of technology integration in the teacher education program affected positively preservice teachers' development of Technology Knowledge and TPACK Efficacy in content areas, as well as enhanced their frequency of effective technology integration in classroom instruction.

Description of Technology Integration

We used students’ self-reported technology integration to examine the enactment of TPACK. Narrative descriptions showed that preservice teachers’ most effective lessons changed from teacher presentations (in early cohorts) to greater student use of technology in later cohorts. For example, Cohort 4 reported 14 occasions in which preservice teachers used technology to show a presentation, 20 occasions where the preservice teacher showed a presentation and students interacted using technology, and no occasions where students created a presentation to demonstrate learning. By Cohort 10 preservice teachers reported their effective technology lessons as five occasions where they created and showed a presentation in teaching, 14 occasions where students interacted with the teacher-made presentation, and five occasions where students created multimedia presentations to demonstrate learning. Two examples of these student-created presentations described by preservice teachers in Cohort 10 included the following:

- “Students were given the chance to create their own presentation using Google Slides. They transferred their own information to create a slideshow on their animal they researched.”
- “The children used Storybird to make their own books.”

When using apps and websites in teaching, preservice teachers reported involving students consistently throughout cohorts. Across all cohorts, preservice teachers reported a total of 21 lessons where they used apps and websites themselves (e.g., to model, record themselves for self-evaluation, or set a timer). They recorded 66 lessons where preservice teachers used apps with students (e.g., to record a student reading for fluency or filling out a Google Doc with students).

One preservice teacher reported, “We passed my iPad around to sort words using iCard Sort during guided reading.” Another preservice teacher said, “I used my iPad and a haiku app with examples of haiku poems and an interactive haiku poem maker.” Another described the following:

> Using this technology [Google Earth] we were able to learn about different geographical features of Brazil, place ourselves on the streets of Sao Paulo, talk about the similarities and differences between the United States and Brazil, and travel from the school to Brazil.

These examples demonstrated the importance of preservice teachers having their own device to use in teaching, as there were limited devices in some classrooms. Preservice teachers reported a total of 167 lessons where students used apps and websites to learn independently. One preservice teacher reported "one-to-one iPad use for an individual student where the student used an application that allowed her to dictate her writing, and translate it into print." Others recorded, "The students had to match the picture with the QR code with the correct word family by scanning the QR code" and "They (students) used computers and went onto Kidblog to type peer feedback." Students held the devices and used them in the learning process.

While most technologies listed were used across subjects, certain technology tools appeared to be used more in specific subjects. For example, when teaching math, preservice teachers reported more instances of projecting examples using a document camera to demonstrate processes and show student work. For instance, a preservice teacher said,

> It is a lot easier to project math manipulatives using the Elmo. It helped ensure that all the students saw what I was doing and how to properly use them. The students got to use the Elmo as well to show how they would solve problems.

Preservice teachers also reported using more review games, such as Kahoot in Math, to involve students using technology in formative assessments. Student online research was reported in multiple areas, including science lessons (14), writing (11), and social studies (9), with students creating presentations or ebooks to report learning in later cohorts.

Preservice teachers noted showing videos to build background knowledge and teach in multiple subject areas, for example:

- "I used videos from National Geographic to support a science lesson."
- "Watched the YouTube video Polygon Song."
- "Used the computer to watch a video on outer space."
- "I used a YouTube video to show to show the students a video about the Revolutionary War."
- "We talked about Amazing Animals and I showed a video about octopuses from PebbleGo."

Teaching using an online curriculum was largely reported in literacy, usually used as an interactive activity led by the preservice teacher before students worked independently on activities at this site. The following examples illustrate this progression from teacher-led to independent student use:

- "Using the Wonders curriculum via Safari on iPad reflected on projector. Activities that correspond with each unit were performed using the iPad."
- "I used the new Wonders online curriculum materials provided by the program for teaching poetry, songs, and sight words."
- "The children were able to use the [Wonders] program during centers to work on reading, vocabulary, fluency, etc."

Another said,

> We use the Wonders website on the Promethean Board to show the intro video for each week, and for the shared read, anthology, and other various functions. The students interact with the Promethean Board through the reading by having the story read aloud to them and also through participating in word sorts and writing answers on the Promethean Board.

As schools added more devices for student use, preservice teachers' use of technology in lessons improved significantly, and the nature of these lessons also changed throughout cohorts. In Cohort 7 a preservice teacher recorded, "The only technology we have available to us is a projector and a Mac computer." Online curriculum uses were first mentioned in Cohort 5 and learning management systems in Cohort 6, indicating when these resources began usage in field experience schools. By Cohort 10 preservice teachers reported involving students with "1:1 Chromebooks using Pear Deck throughout our reading." Another said, "We were learning about geometry (obtuse, acute, and right triangles) in my third-grade classroom. We used the Geoboard app to make triangles."

Discussion

The purpose of this study was to examine the impact of a teacher education program redesign that focused on technology integration by preservice teachers. The first research question asked how preservice teachers' TPACK Efficacy, Technology Knowledge, and Technology Integration frequency changed over time. More specifically the change was evaluated in response to integration of technology practices into the Teacher Education Program.

TPACK Self-Efficacy

The change in the teacher education program has led to an initial jump in TPACK self-efficacy that occurred between baseline and the end of the first semester of program development, suggesting that preservice teachers had significantly increased their beliefs about their ability to integrate technology into content area teaching to achieve the instructional goals. This finding is important, as previous work suggested that preservice teachers' TPACK efficacy beliefs predict their technology integration in the classroom (Abbitt, 2011; Maor, 2016).

The initial jump seemed to be a reaction to the programmatic decision to put an emphasis on technology integration that had immediate impact for preservice teachers through the professional development conferences. The joint participation in conferences on technology integration during student teaching by teacher educators, cooperating teachers, and preservice teachers provided hands-on experience working with technology an resulted in measurable effects emerging from actual classroom. Technology-integrated lessons shared by current classroom teachers provided meaningful ideas for preservice teachers to try out immediately in their student teaching classroom to gain experience and confidence. The usefulness of teacher-led professional development is congruent with previous reports where teacher-led lessons were perceived as more valuable and feasible. Classroom teacher-led professional development facilitated a culture of technology integration much more than did lessons by administrators or curriculum developers (Kopcha, 2012; Liao, Ottenbreit-Leftwich, Karlin, Glazewski, & Brush, 2017).

The importance of practice is also highlighted by the gaps in self-efficacy between the different domains, mathematics and literacy, which are more commonly and consistently taught in elementary classrooms. The practice led to higher rates of efficacy, indicating that practice leads to efficacy.

After the initial jump in self-efficacy, gradual increases were observed in preservice teachers' TPACK efficacy. The slight increases reflected the cumulative effect of the additional components in the program redesign. After the first semester of redesign, new assignments in methods courses required preservice teachers to integrate technology actively to demonstrate content learning. Specifically, distributing 1:1 iPads within method courses and related practica for the semester allowed each preservice teacher to use the device first as a learner and then as teacher.

The rich mastery and vicarious learning experiences that came with multiple components helped build preservice teachers' self-efficacy in integrating technology in classroom and field placement (Bandura, 1997). Moreover, preservice teachers were presented with a new value system that sent a strong message that technology was an important component in teaching and thus should be engaged with (as suggested by Thomas, Herring, Redmond, & Smaldino, 2013).

Technology integration became a focus for preservice teachers as faculty highlighted and modeled it throughout the program. The small incremental increases after the first semester were possibly due to a ceiling effect, as preservice teachers' reported a high mean of TPACK Efficacy at the end of the first semester. Additionally, self-evaluations were likely to be benchmarked to the expectations of technology integration in schools and teacher education classes. As students' understanding of technology became more sophisticated, their self-evaluation shifted to match the new expectations. In other words, preservice teachers had higher expectations for themselves as teachers using technology as they saw others (e.g., instructors and cooperating teachers) who were integrating technology in more challenging ways. The results also suggest that TPACK self-efficacy is a useful early indicator of impact. Conversely, it needs to be supplemented by indicators of actual practice through measures of frequency and content to be able to continuously track growth.

Technology Knowledge

Between the first and second semesters of the program redesign a significant increase occurred in perceived technology knowledge, such as ability to learn new technologies, solve their own technology problems, and have the technical skills to teach well. This growth in technology knowledge was similar to other studies that added some or all of the suggested three TPACK components (Hofer & Grandgenett, 2012) to their teacher education programs (e.g., Chai et al., 2010; Harris & Hofer, 2011; Maor, 2017; Mouza et al., 2014).

Interestingly, reported technology knowledge remained consistently high across cohorts. Technology knowledge has changed in small increments at a rate that was discoverable only across many cohorts (e.g., between Cohorts 2 and 11). Despite the dramatic change in technologies over the 5-year period of this study, preservice teachers' perception of their technology knowledge changed slowly. This finding is most likely because undergraduate preservice teachers are Digital Natives (Prensky, 2001), as they have grown up with technology and, not surprisingly, feel confident using their devices personally. For these students, technology is always changing (Prensky, 2001) and the need to continue learning has become obvious.

Additionally, methods courses in the education program required students to examine and use new technologies, so they practiced experimenting with technologies while planning lessons. This result may have implications for measuring change in technology knowledge. We need to supplement self-evaluation data with observations and qualitative data (e.g., lesson plans) that can provide more practice related indicators of change.

Technology Integration Frequency

Technology Integration Frequency is, most likely, the most important indicator in this study, because it goes beyond knowledge and discusses practice. In examining the trends in technology integration frequency, we found two significant increases. The first took place following integration of technology in methods courses, professional development conferences, and teacher educator training (Figure 2). Mean scores increased from *never use* to *use in a few lessons*, as the use of technology became standard practice in the program.

A second significant increase occurred when all most program components were in place consecutively, including technology course redesign with integration practicum, tablet requirement for all preservice teachers, professional development class for cooperating teachers, and finally a makerspace (between Cohorts 8 and 11). Preservice teachers noted going from *use in a few lessons* to approaching *use in most lessons*. This level of technology integration was higher than what many teachers enact in their classrooms (Bauer & Kenton, 2005; Howard, Chan, Mozejko, & Caputi, 2015). The comparison of the change in self-efficacy and frequency of use shows that frequency of use lags behind self-efficacy and is a harder target to reach. The slower change in frequency of implementation was supported, in part, by the self-efficacy change.

The frequency of actual classroom integration of technology increased gradually across time as each teacher education component was added. This result is consistent with motivation theory (Bandura, 1986; Schunk & Zimmerman, 2007), which suggests that changing the declarative part of motivation and values is easier, as evidenced by the dramatic increase in self-efficacy, while behavioral change lags behind.

Part of the reason for the slow change in practice can be linked to environmental supports (see Figure 1). As the program redesign started to take shape in teacher education classes, the field placement realities were slower to change, often restricting preservice teachers from using technology in more robust ways. Field placement realities serve as a mediator altering the potential link between knowledge and self-efficacy and the frequency of use. Mouza et al. (2014) also noted difficulty placing preservice teachers in classrooms where cooperating teachers were integrating technology well. This disequilibrium was resolved as school districts increased their emphasis on technology integration, providing more devices and professional development for cooperating teachers.

Narrative descriptions of technology use showed a progression of use with whatever tool is used: seeing it modeled, using it as a teacher, using it with students, then letting students use it themselves. This pattern demonstrates how preservice teachers build TPACK efficacy by becoming proficient themselves before having the confidence to use it with students. Preservice teachers also develop technology knowledge working with the device, app, or website. Once these two elements were in place, teachers proceeded to integrate the technology into their teaching, increasing frequency following successful lessons. For a teacher education program, it signaled the importance of modeling tools across the program and making sure that technology integration is addressed in specific courses as well as in field experiences.

TPACK Efficacy and Technology Knowledge Contribution to Integration Frequency

Question 2 examined the contribution of TPACK Efficacy and Technology Knowledge to Technology Integration Frequency in the classroom. Unlike findings in other research (e.g., Abbitt, 2011; Wang, Ertmer, & Newby, 2004), TPACK Efficacy in this study was not a significant predictor of implementation. This lack of prediction may be linked to lack of environmental supports (see Figure 1). For example, a preservice teacher may have high TPACK efficacy, but if there were no devices, no access to the internet, or no permission from the cooperating teacher to use technology, then there would be a lower level of implementation.

Another possible explanation to the lack of predictive power may be linked to the connection between perception and frequency. We pointed to this potential explanation when we discussed the lack of growth in TPACK efficacy after the second semester, despite the growth in implementation. As preservice teachers' perception adjusted to the new expectations and affordances, their self-perception remained similar to that of previous cohorts. This assertion is supported by the shift in qualitative responses showing a growing sophistication across cohorts. While frequency of implementation rose, the TPACK self-efficacy stayed fairly constant effectively, decreasing the correlation between the two.

Technology Knowledge significantly predicted implementation of integration into teaching. Preservice teachers' ratings of their Technology Knowledge affected their frequency of integrating technology into their planning and teaching. As they became more comfortable using devices in university classes, they transferred this knowledge to their teaching in practicum and student teaching. This result is congruent with previous findings that preservice teachers who participate in teacher education programs in which technology is integrated reported more frequent integration themselves (Mouza et al., 2014). Increased knowledge of different technologies enabled preservice teachers to incorporate appropriate apps and websites into lesson planning without adding significantly to planning time. Perceived ability to solve their own technology problems lessened fear of using devices with a class.

Modeling Impacts TPACK Efficacy, Technology Knowledge, and Integration

As hypothesized, modeling directly predicted TPACK Efficacy and Technology Knowledge. Modeling also had a direct effect on Technology Integration Frequency as well as an indirect effect through Technology Knowledge. We view modeling as a measure of deep adoption and commitment by faculty to the technology-infused program (Thomas et al., 2013). In this study, modeling was enacted by teacher educators from all content areas (literacy, math, science, social studies, reading center, and practicum/student teaching) and cooperating teachers in practicum and student teaching. The findings indicated that modeling in teacher education classes and in field experience is a critical component predicting technology knowledge, TPACK efficacy, and integration directly.

The findings confirmed the need for teacher educators and cooperating teachers to talk with preservice teachers about the planning and purpose of what they are observing (Grossman et al., 2009). Preservice teachers can learn and grow vicariously if they understand the decision-making process utilized in integrating technology to create meaningful lessons (Angeli, 2005; Grossman, et al., 2009).

The greatest number of preservice teachers described a cooperating teacher as the most exceptional model in technology integration in all cohorts except 3 and 7, which named a university instructor. This finding was expected, since what a cooperating teacher does in the elementary classroom transfers directly to preservice teachers' teaching (Anderson, 2007). A preservice teacher in Cohort 4 said, "My cooperating teacher does an incredible job of integrating technology into almost every lesson each day. She used the notebooks, tablets, mobi, smartboard, and regular computers on a weekly or even daily basis."

Another comment from Cohort 4 included,

> My cooperating teacher has taught me how to use the smartboard, where to find smartboard lessons. She is learning new things right along with me but she has taught me the basics and enough to get me started and interested. We incorporate the smartboard into almost every lesson.

Preservice teachers described exceptional integration by university instructors that evolved across time, from using technology presentations daily to teach in Cohorts 1 and 2, to Cohort 3 where a preservice teacher noted, “She taught me a variety of educational iPad applications to use.” Indication of a greater coaching role for university instructors was mentioned in Cohort 7:

> “…adding technology when it wasn’t expected and was always willing to explain the technology he was using.”

> “She was always giving suggestions for different apps to use and giving me advice on the apps I was using in class.”

Some preservice teachers listed teachers other than cooperating teachers as exceptional in using technology, along with media specialists, technology coaches, former high school teachers, students they taught, and presenters from the professional development conferences they attended at the university. In each cohort a group always responded that they had not seen anyone who uses technology effectively, a greater number in the initial cohorts while everyone was still learning.

The importance of modeling for effective technology integration in the teacher education program is a key finding of this study. When redesigning programs, the technology and method courses with field experiences are important (Hofer & Grandgenett, 2012); however, the professional development and conference components for teacher educators and cooperating teachers proved to be critical. Once instructors and cooperating teachers felt comfortable using technology themselves, they modeled integration in meaningful ways. Preservice teachers learned vicariously how to plan and teach lessons where students use technology to learn. Then, through field experiences and student teaching experiences they actually taught the lessons planned, receiving feedback from both cooperating teacher and teacher educators.

Conclusion

This study examined the growth of preservice teachers' technology integration in the context of a teacher program redesign as well as factors impacting their technology integration. There was a significant growth in preservice teachers' TPACK efficacy with large effect sizes. This growth was characterized by a major jump in self-efficacy early in the program change, followed by slow incremental change. The results indicated that efficacy was impacted when the program change was initiated and highlighted. It suggests a link between declarative steps and the professional development provided with it as effective bridging steps to increase the probability of preservice teachers engaging with technology integration.

The sense of TPACK self-efficacy is necessary but not sufficient for successful program-wide focus on technology. In short, programs can have immediate impact on preservice teachers even if they are in their student teaching semester.

A growth was also observed in preservice teachers' technology knowledge. The results suggest the redesigned program with multiple components within the framework of TPACK is effective in enhancing preservice teachers' self-efficacy for technology integration, technology knowledge, and frequency of technology use in four subject areas (i.e., literacy, mathematics, science, and social studies) across 11 cohorts from our redesigned teacher education program.

The results also suggest that a focus on technology integration can yield immediate impact on preservice teachers and their motivation to make an effort to increase technology integration. The program produced consistent change in efficacy and knowledge enacted in planning and teaching technology-infused lessons in an actual classroom: TPACK in action (Harris & Hofer, 2011). This result suggests that a declared and consistent effort around technology integration can bring about change and create a self-reinforcing professional development cycle.

Technology knowledge, but not TPACK efficacy, significantly predicted preservice teachers' instructional change with technology integration. The results suggest frequency of technology integration into lessons is related to their technological knowledge but not the efficacy to integrate technology, which may be mediated by conditions in field placement. In addition, both preservice teachers' technological knowledge and the effectiveness of teacher program modeling significantly predicted TPACK efficacy, technology knowledge, and the frequency of technology integration. This finding indicated that faculty support and modeling from university classes and cooperating teachers in practicum is vital for the improvement of preservice teachers' TPACK efficacy, technology knowledge, and actual technology integration in the classroom.

Program components that supported technology integration for faculty and cooperating teachers leading to instructional change were vital. Knowing how to use technology does not equate to perceived ability to teach using technology, so modeling classroom lessons where technology takes learning to another level is important.

Limitations and Further Research

Several limitations should be noted. We did not measure student achievement although it is a critical component in our theoretical model, as the ultimate goal for technology integration. Future research should examine the impact of technology integration on K-12 student outcomes during student teaching and in the first 3 years of teaching to see if technology integration continues and impacts student learning.

Another limitation is that we collected cross-sectional data across 5 years to examine the program's impact on preservice teachers' growth in technology integration. Regardless of the significant growth across cohort, we cannot claim within-group growth.

Last, our study included self-reported data that were not able to provide in-depth information of the quality of student-centered learning during technology-infused lessons through classroom observation. Future studies should include observation of preservice teachers integrating technology in the classroom during student teaching, perhaps following up into their first 3 years of teaching to examine how the redesigned program impacts preservice teachers' careers.

Implications

This multicomponent program redesign enacted over a 5-year period produced preservice teachers who reported each successive semester higher and deeper technology integration. This redesign approach to teacher education programs could be effective at any teacher education program and does not require exclusive attention to technology. To scale the program, we suggest the following as essential components: a shared goal between field placement and teacher education, modeling by teacher educators and cooperating teachers, and an improvement cycle that keeps attending to innovative developments in schools and education writ large.

The heart of change in preservice teacher practice is modeling across the teacher education program. The focus on modeling mandates that faculty and cooperating teachers join together to improve their practice while they support the emerging generation of teachers. Measuring the impact of program redesign requires a multifaceted multimethod approach that combines measures of efficacy (leading indicator), enactment, and even qualitative detail. The cumulative impact of program redesign is large, but it is hard to measure the impact of individual program components that support technology integration on preservice teacher outcomes. At the same time the constant development of new technologies that can support learning forces any program to continuously adapt and add meaningful practices (e.g., makerspaces). Thus, any program that takes adoption of technology into instruction seriously must keep changing and adapting.

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Appendix
Survey Questions

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