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# TPACK Development in Teacher Education: A Longitudinal Study of Preservice Teachers in a Secondary M.A.Ed. Program

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## Abstract

*How does preservice teachers' knowledge for technology integration develop during their teacher preparation program? Which areas of their knowledge develop most naturally, and which areas require more scaffolding? In this mixed-methods, descriptive study of preservice teachers enrolled in an 11-month M.A.Ed. program, we sought to trace the development of participants' technological pedagogical content knowledge (TPACK) over time. Comparisons of self-report surveys, structured reflections, and instructional plans at multiple data points spanning the three-semester program revealed significant development of the participants' technological pedagogical knowledge (TPK) and technological pedagogical content knowledge (TPACK), but only limited growth in technological content knowledge (TCK). (Keywords: TPACK, technological pedagogical content knowledge, technology integration, teacher education, preservice)*

The effective integration of technology in K–12 schools today is an increasingly high priority as schools invest ever-increasing funds in educational technologies. Concurrently, business leaders assert the importance of helping students develop 21st century skills to become productive members of a global economy (Partnership for 21st Century Skills, 2010). Research continues to suggest, however, that technology remains at the periphery of most teachers' practice (Lemke, Coughlin, & Reifsneider, 2009). Recent research, however, also points to promising trends related to teachers' interest in and use of technology in the classroom (Grunwald Associates, 2011; Speak Up, 2011). To capitalize on this increasing access to technology and growing interest on the part of teachers, many educational organizations point to the importance of training both inservice and preservice teachers to more effectively integrate technology into their teaching (International Society for Technology in Education, 2008; Partnership for 21st Century Skills, 2010). Teacher education programs are often seen as the key

catalyst in the preparation of new teachers to integrate technology into their teaching practice. The complex knowledge required to integrate technology effectively, however, proves a significant challenge for both teacher education programs and teacher preparation-related content courses in the arts and sciences. In fact, the National Research Council (2005, 2010) recognizes this need to address technology integration in both content (e.g., undergraduate science and math courses) and instructional pedagogy courses.

Despite the increasing awareness of the challenge of helping preservice teachers to effectively integrate technology into their teaching, the expectation is that teacher candidates will achieve proficiency in technology integration prior to the completion of their teacher preparation program (Council for Chief State School Officers, 2011; National Council for Accreditation of Teacher Education, 2008). With funding from the Preparing Tomorrow's Teachers to Teach with Technology (PT3) federal grant program, teacher education programs throughout the United States have developed specific courses as well as better integration of technology in courses throughout their programs (Rhine & Bailey, 2005). Educational researchers have begun to research the effectiveness of different course structures and emphases on preservice teachers' approaches and abilities to integrate technology into their teaching (Brupbacher & Wilson, 2009; Cavin, 2008; Chai, Hwee, L. Koh, & Tsai, 2010; Jang & Chen, 2010; Kramarski & Michalsky, 2009). However, due to the complexity of the knowledge required to integrate technology effectively in classroom instruction, along with the interconnected nature of this knowledge, there is a need to understand how teacher candidates' knowledge for technology integration develops through course experiences throughout teacher preparation programs. This study assesses and explores this knowledge development of preservice teachers in an 11-month M.A.Ed. initial certification program in secondary education.

The cognitive complexity of teaching is well documented in the teacher education literature (Hammerness, Darling-Hammond, & Bransford, 2005). One framework to help us to delineate and understand this complexity is the Pedagogical Content Knowledge (PCK) framework (Shulman, 1986, 1987). With the development of the PCK framework, Shulman suggested a new way to delineate the knowledge required for effective teaching. Rather than focusing on developing content and pedagogical knowledge in isolation, Shulman (1986) argued that a teacher's understanding of how to bring together his or her content and pedagogical knowledge is the key to effective teaching practice. It is in this intersection of content and pedagogical knowledge that teachers are best able to anticipate students' learning needs for a particular topic or concept, select the optimal instructional approach(es), and understand how to scaffold the learning experience for students. Since the development of the PCK framework, many teacher education programs have been redesigned to assist teacher candidates in developing their PCK through content-specific methods, planning, and field experience coursework.

In the mid-1980s, when Shulman first introduced PCK, the range and complexity of commonly available technology tools and resources was relatively limited. Although one can argue that learning how to thread a filmstrip projector required specific training and experience, the knowledge required to operate many of the technologies of the time was subsumed in pedagogical knowledge in the PCK framework. In the intervening years, however, the number, range, and complexity of educational technology tools and resources available in classrooms, along with their instructional capabilities, have increased dramatically. The knowledge required to operate and make use of these technologies certainly goes well beyond pedagogical knowledge in the PCK framework. Recognizing this limitation in the PCK framework, Mishra and Koehler (2006) argue that technological knowledge (TK) should be added as a third domain of knowledge in the PCK framework. They define TK as the "knowledge about standard technologies, such as books, chalk, and blackboard, and more advanced technologies, such as the Internet and digital video (p. 1027)." This domain of knowledge also includes the skills necessary to operate the technologies. By adding this third domain, Mishra and Koehler created the Technological Pedagogical Content Knowledge (TPCK or TPACK) framework.

By adding technological knowledge to the PCK framework, they have created three new intersections of teacher knowledge: technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK). Mishra & Koehler (2006) define technological content knowledge (TCK) as, "… the knowledge about the manner in which technology and content are reciprocally related" (p. 1028). They further suggest, "Teachers need to know not just the subject matter they teach, but also the manner in which the subject matter can be changed by the application of technology" (p. 1028). This reciprocal nature of TCK can be seen most clearly in the physical sciences, where advances in technologies literally change and expand scientists' understanding of the natural world (Harris, Mishra, & Koehler, 2009). Another way to understand TCK is that it represents the knowledge required to identify and select technology tools and resources in a particular content area. For example, for a mathematics teacher to select the appropriate virtual manipulative to support the learning of a particular curriculum topic, she must draw on her TCK.

Technological pedagogical knowledge (TPK) can be defined as: "the knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies" (Mishra & Koehler, 2006, p. 1028). TPK, in essence, is the knowledge that helps teachers to maximize a particular technology's affordances to support a pedagogical strategy or model. For example, when selecting an appropriate social networking environment to support a problem-based learning experience in a science class, the teacher must match the particular

features (and constraints) of the social networking platform to support effective communication and collaboration in the PBL experience.

TPACK is the domain of knowledge where all the forms of a teacher's knowledge intersect. This is the form of knowledge that is required to plan and implement successful technology-infused learning experiences. Mishra and Koehler (2006) describe TPACK as:

> …the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones (p. 1029).

Note that TPACK is more than merely the sum of the parts. It is TPACK that enables a teacher to determine a "fit" between the curriculum focus, pedagogical strategies, and digital or nondigital technologies. For example, to support an historical inquiry project using historical documents, it is not enough for a teacher to understand the historical context, how to structure student research, and how to find access to historical documents either in print form or online. Rather the teacher must draw on her content knowledge and pedagogical experience to identify an appropriate Web-based archive of primary-source documents relative to the content focus, understand how to navigate the archive and to help the students do so, and identify the most effective strategies to enable students to work collaboratively to not only find material in the archive but also make sense of it to build their understanding of the topic at hand. Clearly, the complexity of this kind of synergistic and interdependent knowledge provides significant challenges to educational technology instructors, researchers, and teacher preparation programs.

The introduction of TPACK as a construct for understanding the teacher knowledge required for technology integration has catalyzed a flurry of scholarly inquiry. According to the TPACK Wiki (Koehler, 2012), there have been more than 500 publications and presentations related to TPACK since the construct's development in 2005. Interestingly, the TPACK special interest group (SIG) is now the second largest SIG in the Society for Information Technology and Teacher Education (SITE). In fact, at the 2012 SITE conference, the TPACK strand consisted of 78 presentations, posters, and roundtables—second only to sessions focused on distance learning. Early work in TPACK focused primarily on understanding the construct (e.g., Archambault & Barnett, 2010; Koehler & Mishra, 2009; Mishra, Koehler, & Henriksen, 2011) and how TPACK is operationalized in teacher planning (e.g., Harris, Mishra, & Koehler, 2009; Mouza & Wong, 2009) and practice (e.g., Cox & Graham, 2009; Hofer & Swan, 2008). More recently, researchers have

begun to focus on specific approaches to helping preservice and inservice teachers develop their TPACK (e.g., Cavin, 2008; C. R. Graham et al., 2009) and on developing, validating, and applying instruments to measure TPACK in a variety of ways (e.g., Hofer & Harris, 2010; Schmidt et al., 2009).

In teacher preparation programs, teacher candidates can develop their TPACK in a variety of courses and field experiences. The three primary foci for developing TPACK are through a dedicated educational technology course, content-specific teaching methods, or practicum courses; or through the duration of coursework in a teacher preparation program. In the section that follows, we review a selection of research studies that track preservice teachers' development of TPACK in each of these primary areas.

## Educational Technology Courses

One primary way that teacher educators can help preservice teachers develop their TPACK is through focused work in an educational technology course. In fact, the majority of teacher preparation programs accredited by the National Council of Accreditation for Teacher Education (NCATE) require at least one educational technology course (Kleiner et al., 2007). A number of researchers have begun to explore the efficacy of different approaches to TPACK development in the educational technology course. One strategy to determine growth in TPACK over time is to employ assessments before and after exposure to a treatment. In their study of preservice teachers in an educational technology course in Singapore, Koh, Chai, and Tsai (2010) used an adaptation of the Survey of Preservice Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009) at the beginning and conclusion of a 3-credit course. Chai et.al conclude that participants ($n = 365$) made significant gains in CK, PK, TK, and most substantially in TPACK with moderately large effect sizes. In analyzing interactions between the domains, the findings suggest that PK had the largest impact on TPACK. Hu and Fyfe (2010) completed a similar study using a modified version of the Schmidt et.al instrument in an educational technology course redesigned around TPACK principles in Australia. The course was organized around a series of problem-centered design tasks inspired by Mishra and Koehler (2006). Postcourse survey results indicated that the teachers' confidence in their ability to connect their use of technology with content and pedagogy increased significantly.

Other researchers attempt to understand TPACK development through multiple data sources. Cavin (2008) presents findings on a study that focused on helping preservice teachers develop their TPACK through microteaching lesson study. The six participants worked in two groups to develop technology-enhanced lessons through a recursive process of microteaching, reflection, and revision. Data consisted of audio recordings of group meetings, videos of microteaching, written reflections, and interviews. Participants initially focused primarily on the use of technology to promote procedural

understanding in mathematics and science. As they progressed through the course, however, the participants' thinking shifted to a more conceptual focus using technology tools, indicating a growth in their TPACK. Similarly, the participants began to become more sophisticated in their selection of pedagogical strategies and employed a more student-centered approach to technology integration.

Koh and Divaharan (2011) explore the efficacy of a new instructional model in an educational technology course designed to help students develop their TPACK through a series of three phases: fostering acceptance of a new ICT tool through faculty modeling, building technical proficiency, and developing technology integration experience through design projects. This study focused on the development of preservice teachers' ($n = 74$) TPACK in their design project that involved using interactive whiteboards (IWBs) to support classroom instruction. Data for the study consisted of short, structured student reflections at the end of each of the three phases of the instructional model as well as pre/post surveys focused on participants' confidence and attitudes toward the use of the IWB. The reflections were coded according to the different domains of the TPACK construct. The researchers suggest that the model helped students build their confidence in integrating whiteboard technology into their teaching. Their positive attitude toward IWBs was high at the beginning of the study and remained high throughout. Initially, participants' reflections focused on developing technical competency, or TK (58%), slightly less so with TPK (33%), and only minimally on TCK (7%) or TPACK (2%). In Phase 2, students emphasized TPK-related reflections (52%) and de-emphasized focus on TK (35%). Comments related to TCK and TPACK remained limited (5% and 3%, respectively). These percentages held true at the end of the third phase, with a slight growth in TPK (55%) and a decrease in TCK (5%).

In a study of preservice secondary science teachers in Israel, Kramarski and Michalsky (2009) explored three metacognitive approaches in an online learning environment. The students ($n = 144$) were enrolled in a Designing Learning Activities with a Web-Based Environment course and randomly assigned to one of three approaches to helping them develop their TPACK: planning prompts, action and performance prompts, or reflection prompts. All three groups worked on activities to help them build their comprehension of TPACK through an analysis of video vignettes of technology integration and the design of technology-integrated learning experiences. In the planning-prompts group, participants were prompted with comprehension questions to focus on the video analysis task and before designing the activity. In the action and performance group, students were prompted with strategy questions during the planning process to help them structure their lessons. The reflection-prompts group responded to structured reflection questions after completing the analysis and planning to evaluate their work. Kramarski and Michalsky report that all three groups improved their

TPACK, but it was unclear how the tasks and/or analysis of data linked to specific elements of the TPACK construct.

## Content-Specific and Teaching Methods Course Experiences

Increasingly, researchers are exploring efforts to assist preservice teachers in developing their TPACK in the context of content-specific teaching methods and field experience courses. Özgün-Koca, Meagher, and Edwards (2010) conducted a study of students in a mathematics teaching methods course (*n* = 20) using a pre/posttest design with the mathematics technology attitudes survey (MTAS), three short student feedback surveys during the course, and a final open-ended exit interview. Throughout the course, the instructor modeled a variety of technology-enhanced learning activities with an emphasis on TPK. Students completed problem sets that helped them develop their PCK, developed and implemented two technology-infused lessons, designed five mathematics activities using graphing calculators, and conducted original research focused on teaching a secondary mathematics problem using the graphing calculator. Findings suggest that students' understanding of technology in mathematics teaching shifted from thinking of technology as a tool for reinforcement to the use of technology as a tool to help students develop their conceptual understanding of mathematics. However, the students also retained skepticism about the appropriateness of using technology to help develop mathematics concepts.

Jang and Chen (2010) examine the use of a transformative model of integrating technology with peer coaching for helping preservice secondary science teachers develop TPACK. The participants included 12 preservice science teachers in a Pedagogical Content Knowledge in Science and Technology course in Taiwan. Data consisted of written assignments, online data, reflective journals, videotapes, and interviews. This transformative model, around which the course was structured, consisted of four components: comprehension, observation, practice, and reflection. Students completed activities aligned with each component of the model. For example, in Phase 3, TPACK Practice, students designed and implemented a 30-minute microteaching technology integration activity that they presented in the class. This implementation was followed by a guided reflection assignment. The researchers suggest that the model helped the participants better understand PCK and TPACK. Additionally, the participants were able to model their own technology integration lessons after those of their mentors. The analysis and reflection on video recordings of their lessons helped them synthesize their knowledge of "students' learning difficulties (relative to specific content foci), instructional strategies, and technology" (p. 562).

In a cross-case study of four preservice elementary teachers' efforts to integrate technology into their 7 weeks of practice teaching experiences, Figg and Jaipal (2009) used multiple data sources including questionnaires, interviews, and classroom observations. The researchers organized a design-team

experience in which the preservice teachers collaborated with their supervising teachers and technology consultants to design and implement a series of technology-integrated lessons. The researchers observed the lessons and debriefed with the preservice teachers following each lesson. The researchers also provided supports for the participants, including tutorials and tips for using selected technologies, individual training on particular resources, and additional instructional support in the teacher lab. Figg and Jaipal report that the participants were successful both in designing and implementing the lessons as well as developing their TPACK over the duration of the project. They state, "TPK characteristics played the most significant role in successful planning and implementation, and the lack of these foundational understandings had a negative impact on lesson implementation in practice" (p. 4). They recommend a strong focus on instructional planning and implementation strategies as a way to provide key assistance for preservice teachers.

## Longitudinal and Integrated Coursework Studies

The remaining four studies reviewed here explore TPACK development either throughout or at the end of teacher preparation programs. Pierson (2008) investigates how undergraduate elementary preservice teachers work to develop their TPACK through the use of edited teaching videos during student teaching. Students identified an instructional dilemma in their teaching, planned a lesson to address the challenge, and arranged for the lesson to be video recorded as they taught the lesson. Immediately before and immediately following the implementation of the lesson, the students wrote reflective statements and then edited the teaching video into a 5-minute teaching episode. Finally, they shared and discussed this episode with a peer group using structured discussion questions. They then wrote a final reflection following this discussion. Eleven students from the cohort created lessons that used technology and thus became the focus for this study. Students reported finding value in editing and reflecting on the videotaped lessons. In this initial reporting of the results, however, Pierson offers little evidence of TPACK growth through this experience.

Akkoç (2011) explored how two preservice mathematics teachers in Turkey integrated technology into their lessons to address student difficulties. The researchers collected data during two courses: an educational technology course and a mathematics methods course. Through student interviews, lesson plans, notes, and videotapes of microteaching experiences, the researcher concluded that students' TPACK developed significantly over the course of two content-centered microteaching experiences. Erdogan and Sahin (2010) report on a study of preservice mathematics teachers in Turkey ($n$ = 137, 38 secondary and 99 elementary). The researchers developed and validated a scale of students' perceptions of TPACK that students completed near the end of their teacher education program. Findings suggest that elementary teacher candidates report more competencies in all seven TPACK

domains than the secondary teacher candidates. The authors suggest that this may be because TPACK is typically emphasized more in the elementary program. Male teacher candidates reported more competency than females.

Only one study focused on teacher candidates' development over time in their teacher preparation programs. Niess (2005) reports on preservice mathematics and science teachers' development of their TPACK throughout the course of their one-year graduate-level teacher preparation program for science and mathematics. The development of the teacher candidates' TPACK was a focus of the program and was operationalized in the form of a technology integration theme that was embedded in multiple courses, including microteaching experiences and full-time student teaching, throughout the program. Niess reports that by the end of the program, 14 of the 22 students in the cohort met the TPACK outcome of "using technologies to engage students in learning science and mathematics" (p. 514), as measured by university supervisors, cooperating teachers, and the students themselves. To describe the differences in students' TPACK development, Niess shares five case studies. She concludes that "only some of these student teachers seemed to recognize the interplay of technology and science despite the emphasis throughout the program" (p. 520).

### Synthesis of Extant Research on the TPACK Development of Preservice Teachers

The 13 studies reviewed here exemplify the teacher education community's interest in how TPACK develops for preservice teachers. Additionally, various results-related trends are beginning to emerge in this area. First, the studies reviewed here seem to demonstrate that preservice teachers do begin to develop their TPACK in both single courses and through more integrated approaches of infusing technology in teacher preparation programs. What is unclear in the research so far, however, is how knowledge develops in different domains (i.e., TCK, TPK) and how this knowledge develops over time throughout an entire teacher preparation program. The purpose of this study is to extend the TPACK development literature, providing some insight into how this knowledge develops in a typical three-semester teacher preparation program. Specifically, the study is focused on the following research questions:

- How, if at all, does preservice teachers' TPACK develop throughout their teacher education program in terms of TCK, TPK, and TPACK?
- How, if at all, is TPACK development reflected in preservice teachers' lesson/unit planning materials and reflections upon planning?

## Methodology

### Site Description

We conducted the study at a Mid-Atlantic university offering a three-semester master's in education initial licensure program in secondary

**Table 1.** Coursework in the M.A.Ed. Program

| Semester 1: Summer | Semester 2: Fall | Semester 3: Spring |
| --- | --- | --- |
| Educational Psychology (3 credits) | Curriculum and Instructional Methods (in content area) (3 credits) and Practicum (1 credit) | Assessment of Learning (1 credit) |
| Social, Philosophical, and Historical Foundations of Education (2 credits) | Content Reading and Writing (2 credits) and Practicum (1 credit) | Collaborating with Families and School Personnel (3 credits) |
| Research Methods in Education (3 credits) | Designs for Technology-Enhanced Learning (2 credits) | Instructional Planning in (content area) (2 credits) and Practicum (1 credit) |
| Current Issues in Curriculum, Instruction, and Assessment (3 credits) | Classroom Adaptations for Exceptional Students (1 credit) | Secondary Curriculum and Instruction Seminar (1 credit) |
| | Classroom Organization, Management, and Discipline (1 credit) | Internship in Supervised Teaching (7 credits) |
| | Characteristics of Exceptional Student Populations (1 credit) | |
| | Differentiating and Managing in Diverse Classrooms (1 credit) | |
| | Adolescent Literature (for English students) (3 credits) | |

(grades 6–12) education. Students who have already earned a baccalaureate degree in a particular discipline (e.g., mathematics, biology) are admitted into the M.A.Ed. program in the spring semester and begin coursework in two 5-week summer sessions. The students who participated in the study were part of a cohort that moved through the teacher preparation program together during the three-semester program. See Table 1 for an overview of the program coursework.

In their first semester in the program, the participating students enroll in four courses spanning two summer sessions. This foundational coursework is comprised of 3-credit courses in social and historical foundations of education, current issues and trends in curriculum and instruction, educational psychology, and educational research.

In the second semester of the program, students in all content areas (English, foreign language, mathematics, science, and social studies) are enrolled in the appropriate content-based teaching methods course, which includes a 20-clock-hour practicum experience; content reading and writing, which includes a 20-clock-hour practicum; an educational technology course; and a set of four coordinated one-hour courses that focus on students with special needs and classroom management. Secondary English students also take a course on adolescent literature. During this semester, each student is placed into a classroom for a practicum experience that will later serve as a student-teaching placement.

Technology is addressed most intentionally in the required educational technology course during the second semester. In the course, students

**Table 2.** Technology Integration in Teaching Methods Courses

| English Methods | Mathematics Methods | Science Methods | Social Studies Methods |
|---|---|---|---|
| Concept-mapping software | Use of physical and virtual manipulatives | Use of physical and digital scientific probes | Digital archives of historical documents |
| Use of document camera | | | |
| | Graphing calculators | Concept-mapping software | Use of wikis for collaborative work |
| Word commenting and revision features | | | |
| | Mathematical software (e.g., Geometer's Sketchpad, | Digital microscopy | |
| | | | Use of film and video |
| Use of film, video, and music | TinkerPlots) | Data analysis software | |

explore a variety of ways that technology can support curriculum-based teaching and learning. Specifically, they explore and work with a variety of both general and content-specific technology tools and resources and their instructional application. They develop a number of applied and reflective course assignments that help them make connections between the technology and their teaching discipline. The capstone project in the course is the design and development of a technology-integrated lesson plan in the format of their teaching methods course.

In addition to the educational technology course, the program also addresses technology to varying degrees in the required teaching methods courses. For a brief summary of the types of technologies addressed in each of the methods courses, please see Table 2.

In the final semester of the program, students take three courses during the first 5 weeks of the semester, including a course in classroom-based assessment, collaboration with families and school personnel, and a content-based instructional planning course that includes a 20-hour practicum experience. For the remaining 11 weeks of the semester, students complete their student teaching experience, which also includes a one-credit content-based student teaching seminar. Upon completing student teaching, the candidates present an electronic teaching portfolio of their work throughout the program to the faculty that they develop throughout their program and, if successful, earn their master's degree and state teaching license.

## Data Sources

Data was generated for the study from summer 2009 through spring 2010. We collected three primary data sources at multiple points during the program. The four key data collection points were spaced throughout the program: at the beginning of the students' first summer course, at the beginning of the fall semester, at the end of the fall semester, and at the end of the spring semester. Please see Table 3 (p. 94) for an overview of the data sources and collection points. At each of these four points, students completed Schmidt et. al's (2009) TPACK survey with multiple items keyed to each of the seven types of knowledge represented in the TPACK construct: technological (TK), pedagogical (PK), content (CK), technological pedagogical (TPK), technological content (TCK), pedagogical content (PCK), and

**Table 3.** Overview of Data Sources and Collection Points

| Start of Summer | Start of Fall | End of Fall | End of Spring |
|---|---|---|---|
| TPACK Survey | TPACK Survey | TPACK Survey | TPACK Survey |
| Lesson snapshot and reflection | Lesson snapshot and reflection | Lesson snapshot and reflection | Lesson snapshot and reflection |
| | | Lesson plan 1 | Lesson plan 2 |

**Table 4.** Focus Group Self-Report TPACK Survey Means

| Domain of Survey<br>Main Focus Group of Students (N = 8) | Summer Mean | Fall Pre Mean | Fall Post Mean | Spring Mean |
|---|---|---|---|---|
| TK: Technology Knowledge | 3.39 | 2.85 | 3.73 | 4.00 |
| CK: Content Knowledge | 4.33 | 4.13 | 4.54 | 4.80 |
| PK: Pedagogical Knowledge | 3.50 | 3.85 | 4.10 | 4.36 |
| PCK: Pedagogical Content Knowledge | 3.25 | 3.80 | 4.25 | 4.28 |
| TCK: Technological Content Knowledge | 2.75 | 3.00 | 4.25 | 4.28 |
| TPK: Technological Pedagogical Knowledge | 2.92 | 3.28 | 4.52 | 4.51 |
| TPACK: Technology Pedagogy and Content Knowledge | 3.02 | 3.12 | 4.33 | 4.31 |

technological pedagogical content knowledge (TPACK). Participants also completed a snapshot and reflection assignment at all four data points. This assignment asked students to provide a brief description of how they would imagine technology used effectively in a lesson or project in their content area. It also asked students to reflect on when it is appropriate to integrate technology into teaching and when it is not appropriate to do so. Finally, students completed two lesson plans: one during the fall semester that they created for their educational technology course, and one that they designed and taught during their student teaching in the spring semester. The lesson plan in the fall included a reflection section in which students discussed how they saw the use of technology connecting to their learning goals and instructional strategies. One of the researchers observed the lessons taught during student teaching to observe how the written plan diverged from the lesson design, if at all. In lieu of a written reflection statement for the second lesson plan, the researcher who observed the lesson interviewed each student following the lesson to better understand how they envisioned the use of technology supporting teaching and learning. These interviews were audio recorded and transcribed for analysis and essentially represented an audio-recorded version of the lesson plan that was similar to the first written lesson plan. We collected all of the data and assigned each participant a code that enabled us to group the data for each participant.

## Data Analysis
To carefully examine and interpret the data sets over time and to minimize the impact of missing data within the context of the longitudinal study, we
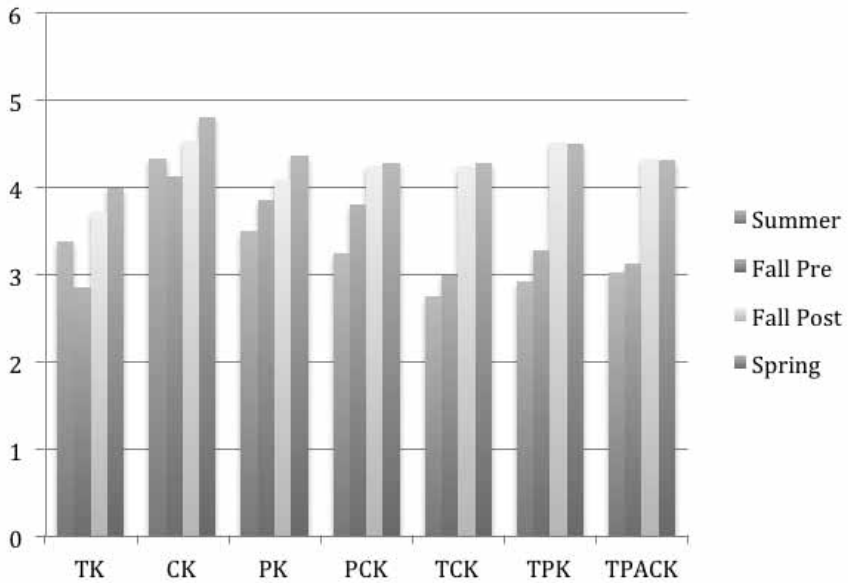
*Figure 1*. TPACK Survey means displayed graphically across the four data points.

selected two students from each of four disciplines (English, mathematics, social studies, and science) to provide a more focused subset group for analysis. We also used this strategy to more equally represent the four disciplines. We recognized that some statistical power would be lost by not including all of the original 17 students available for analysis, but when carefully examining the fact that 30–40% of the data was missing for some data points for some students, we determined that we could accomplish a more focused analysis and interpretation process by limiting the longitudinal investigation to only eight students, balanced across the four disciplines, with all data intact. Two professional statisticians who reviewed the raw data spreadsheets confirmed this decision. We then analyzed the data from these eight students by semester and examined it for individual trends across the duration of the program.

**Survey analysis.** To help us to understand the participants' view of the progression of their knowledge for technology integration, we summarized the TPACK survey results from the focus group of students at each of the four data points (summer, beginning of fall, end of fall, and end of spring) using the survey subcategory means as recommended by Schmidt et. al (2009). These categories included TK, CK, PK, PCK, TCK TPK, and TPACK. Within the survey categories, we used a 5-point Likert confidence scale with a score of 1 representing low confidence and 5 representing high confidence. We then computed and charted the means for each subcategory across the three semesters for a descriptive snapshot of the trends across the program in survey results. Table 4 displays the result, and Figure 1 charts

them for visual interpretation. As can be more easily seen in the chart, there is an observable growth during the fall semester for all categories, but particularly for the more integrated categories of PCK, TCK, TPK, and TPACK. As mentioned previously in the program description, the fall semester is when the students took their educational technology and first teaching methods courses.

**Lesson plan and reflection analyses.** To analyze the reflection statements, interviews, and lesson plans, we worked in pairs to assess and code the documents. The discipline-specific nature of the TPACK framework also required us to collaborate with content experts to examine the data in the four content areas: mathematics, science, secondary English, and social studies. One of the researchers collaborated with a teacher educator in each discipline to assess the quality of technology integration in the lesson plans using a validated, TPACK-based Technology Integration Assessment Instrument (Harris, Grandgenett, & Hofer, 2010). Each pair of scorers reached consensus on the scores for the lesson plans. We recorded this data, which include independent measures of TPK, TCK, and TPACK, in a spreadsheet for analysis. In addition, each pair of researchers also coded the snapshot and reflections, lesson plan reflections, and interview transcripts to collaboratively reach consensus using TPACK-based codes developed for an earlier study focusing upon TPACK in instructional planning (Harris & Hofer, 2011). Following this coding, we tabulated the number of TPACK-related codes within and across participants for each of the four data points, entering this information into a spreadsheet. In addition, we used grounded theory (constant comparative) methods to identify trends in students' thinking and overall themes across participants. For sample reflective statements across the data points for one of the participants, see Table 5.

The results for the TPACK-related rubric scoring of the lesson plans follow in Table 6 (p. 98), which displays the lesson-plan scores for each row of the rubric for each student in the focus group, along with their total rubric score for the lesson. We computed means and standard deviations as well. Each row of the rubric identifies a key element of TPACK, including Row 1: Curriculum Goals and Technology (TCK), Row 2: Instructional Strategies and Technology (TPK), Row 3: Technology Selection (TPACK), and Row 4: Fit (TPACK). As can be seen from the total rubric scores, there is a slight dip from the total rubric scores for Lesson 1 (fall post) to the total rubric scores for Lesson 2 (spring), with means of 13.63 and 11.63 respectively. However, a two-tailed paired t-test indicated that this dip is not statistically significant ($t = 1.78$, df = 7, $p < .117$).

For the qualitative codes for the reflection statements, we summarized the codes for TPK, TCK, and TPACK for each of the eight focus groups across the four data points (summer, fall pre, fall post, spring). We also computed means and standard deviations. Within the scoring process, we noted that it was actually easier to score the reflection statements than the

**Table 5.** Summary of Data Collection and Samples

| Stage of Program | Data Collection | Data Samples |
|---|---|---|
| **Summer** | | |
| In the summer, students enrolled in four 3-credit foundational courses (educational psychology; foundations of education; educational research, and current issues in curriculum, instruction, and assessment). In the last course, students begin to think about designing instruction and co-construct a brief multidisciplinary unit in small groups. | Students completed the TPACK self-report survey and a lesson snapshot and reflection on the role of technology in education at the beginning of their summer coursework. | In one student's lesson snapshot and reflection, the student stated: Since I have just started the program, my ideas are probably limited. I want to teach high school English, and trying to incorporate technology is hard for me to grasp when dealing with texts. I could use a PowerPoint presentation, but I feel that is not enough to clearly use technology effectively. |
| **Fall** | | |
| In this semester, students enroll in their content-specific teaching methods course and practicum, content reading and writing and practicum, educational technology, and four one-credit courses focusing on students with special needs. | Students completed the TPACK self-report survey and a lesson snapshot and reflection at the beginning and end of this semester. In addition, each student created a technology-integrated lesson plan during the educational technology course. | In her lesson snapshot and reflection at the end of the semester, the student stated: Technology is important in a classroom when it has a purpose. It should support student learning, not distract from it. Many teachers use technology, and it appears forced. By being a support for the lesson, it can provide an engaging and memorable experience for the students. For her lesson plan, she used a series of targeted streaming video clips to help students build their understanding of personification in literature. |
| **Spring** | | |
| This semester begins with students taking a series of classes in the first 5 weeks, including instructional planning, assessment, and collaborating with families and school personnel. At the end of these courses, students begin their 10-week full-time student teaching experience. | Students completed the TPACK self-report survey and a lesson snapshot and reflection on the role of technology in education at the end of their student teaching. In addition, they created at least one technology-integrated lesson that they taught during their student teaching followed by an interview with one of the researchers. | In her final reflection, one student compared her current understanding with her first reflection. She stated: In my first reflection, I did not fully understand that technology use had to be tied to specific learning objectives and activity types. I somewhat understood that content needed to be the main focus, but it did not even occur to me to think about specific learning objectives and activity types (this was the main difference). What has led to the differences in my reflections is everything that I learned in my technology course at ___. I learned how and WHY technology needed be grounded in learning objectives and the negative side of what happens when it is not. I also had the opportunity to plan a formal tech-enhanced lesson where I had to implement this way of thinking about technology, and it really solidified my understanding of the appropriate use of technology. |

**Table 6.** Overview of Lesson Plan Rubric Scores

| Student ID | Lesson 1 Rubric Scores (Fall Post) | | | | | Lesson 2 Rubric Scores (Spring) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Row 1 | Row 2 | Row 3 | Row 4 | Total Rubric | Row 1 | Row 2 | Row 3 | Row 4 | Total Rubric |
| Student 1 | 3 | 4 | 3 | 4 | 14 | 3 | 3 | 3 | 2 | 11 |
| Student 2 | 4 | 4 | 4 | 4 | 16 | 3 | 2 | 3 | 2 | 10 |
| Student 3 | 4 | 4 | 3 | 4 | 15 | 4 | 4 | 3 | 4 | 15 |
| Student 4 | 3 | 3 | 3 | 3 | 12 | 3 | 3 | 3 | 3 | 12 |
| Student 5 | 3 | 3 | 3 | 3 | 12 | 3 | 3 | 3 | 3 | 12 |
| Student 6 | 4 | 3 | 3 | 3 | 13 | 3 | 2 | 3 | 3 | 11 |
| Student 7 | 2 | 3 | 3 | 3 | 11 | 3 | 4 | 3 | 3 | 13 |
| Student 8 | 4 | 4 | 4 | 4 | 16 | 2 | 3 | 2 | 2 | 9 |
| Mean | 3.38 | 3.50 | 3.25 | 3.50 | 13.63 | 3.00 | 3.00 | 2.88 | 2.75 | 11.63 |
| *SD* | 0.74 | 0.53 | 0.46 | 0.53 | 1.92 | 0.53 | 0.76 | 0.35 | 0.71 | 1.85 |

lessons themselves, as the reflection statements were generally more detailed and provided a more clearly described rationale for the instructional decisions that the students had made. In other words, their thinking was often more transparent in the reflections. Within the table of qualitative code results (Table 7), it was apparent that the TPK category was consistently higher than the TCK and TPACK categories for each semester. Paired *t*-tests conducted for each semester's data between the TPK and TCK and the TPK and TPACK categories indicated significance in these category differences for at least the $p < .05$ level of significance for each pairing.

Similar to the qualitative codes for the reflection statements, Table 8 displays the qualitative codes for the lessons for the TPK, TCK, and TPACK categories for the two data points for this analysis, which consisted of the first lesson in the fall post period and the second lesson as documented in the spring semester. We also computed the means and standard deviations for all categories. In results consistent with the qualitative codes for reflections analyses, the TPK category codes far outnumbered the TCK and TPACK codes. Paired t-tests comparing the TPK to TCK and TPACK categories again indicated statistical significance in these differences for at least the $p < .05$ level.

## Discussion

### Key Findings
Over the course of the teacher education program we examined, survey results seem to indicate overall strong growth in TPACK. The largest surge in means in each area of knowledge (e.g., PCK, TCK) occurred during the fall semester. This gain makes sense in the context of the teacher preparation program because this is the point of the program in which the students are enrolled in their educational technology course and their first teaching methods course. It is during this semester that students are

**Table 7.** Qualitative Codes for Reflections

| Student | Summer Pre | | | Fall Pre | | | Fall Post | | | Spring Post | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TP | TC | TPACK | TP | TC | TPACK | TP | TC | TPACK | TP | TC | TPACK |
| Student 1 | 1 | 1 | 3 | 1 | 0 | 0 | 3 | 1 | 0 | 0 | 0 | 0 |
| Student 2 | 3 | 3 | 0 | 9 | 0 | 1 | 3 | 0 | 1 | 5 | 0 | 0 |
| Student 3 | 0 | 0 | 0 | 5 | 0 | 1 | 4 | 1 | 0 | 7 | 0 | 1 |
| Student 4 | 2 | 2 | 0 | 3 | 2 | 0 | 3 | 2 | 1 | 7 | 2 | 0 |
| Student 5 | 5 | 5 | 0 | 3 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 2 |
| Student 6 | 2 | 2 | 0 | 6 | 0 | 0 | n/c | n/c | n/c | 6 | 0 | 0 |
| Student 7 | 1 | 1 | 3 | 2 | 0 | 1 | 4 | 0 | 2 | 6 | 0 | 0 |
| Student 8 | 4 | 4 | 1 | 12 | 3 | 4 | 13 | 0 | 6 | 10 | 0 | 2 |
| Mean | 2.25 | 0.88 | 0.88 | 5.13 | 0.63 | 0.88 | 4.57 | 0.57 | 1.43 | 5.25 | 0.38 | 0.63 |
| Std. Dev. | 1.67 | 0.64 | 1.36 | 3.76 | 1.19 | 1.36 | 3.78 | 0.79 | 2.15 | 3.28 | 0.74 | 0.92 |

**Table 8.** Qualitative Codes for Lessons

| Student | Fall Post | | | Spring | | |
|---|---|---|---|---|---|---|
| | Lesson 1 TP | Lesson 1 TC | Lesson 1 TPACK | Lesson 2 TP | Lesson 2 TC | Lesson 2 TPACK |
| Student 1 | 9 | 1 | 0 | 6 | 0 | 3 |
| Student 2 | 5 | 0 | 1 | 6 | 0 | 0 |
| Student 3 | 8 | 0 | 3 | 7 | 0 | 0 |
| Student 4 | 4 | 0 | 0 | 7 | 0 | 2 |
| Student 5 | 2 | 1 | 2 | 5 | 0 | 1 |
| Student 6 | 7 | 0 | 2 | 8 | 0 | 0 |
| Student 7 | 2 | 1 | 1 | 14 | 0 | 0 |
| Student 8 | 14 | 0 | 3 | 11 | 0 | 0 |
| Mean | 6.38 | 0.38 | 1.50 | 8.00 | 0.00 | 0.75 |
| Std. Dev. | 4.03 | 0.52 | 1.20 | 3.02 | 0.00 | 1.16 |

assisted in thinking systematically about teaching strategies, instructional planning, and technology integration. Although a similar "methods bump" may be seen in any teacher education program, at least part of this increase can probably be explained by the integrated nature of the technology and methods courses in this particular program. The educational technology course is taught more like a methods course than a skills-based course, with many opportunities for students to apply what they are learning in the technology course to their methods coursework (for a more detailed discussion of the structure of the course, see Hofer & Harris, 2010). Perhaps most significantly, students develop the technology-infused lesson plan for the technology course in their instructor's required format and often turn in this lesson plan as part of the methods course requirements. This connection between the technology and methods course affords students the opportunity to receive feedback on their technology integration planning from the

perspective of educational technology as well as teaching in their discipline. This finding echoes the repeated calls for a more integrated approach to technology preparation throughout program work (see Mehlinger & Powers, 2002). Contrary to what we note in the section below, there was no apparent "dip" in TPACK scores during the student teaching semester. Thus, although there was not substantial growth during the final semester of the program, it seems that the students retained their confidence regarding their technology integration knowledge even during the stressful and often overwhelming experience of student teaching.

Although the expressed level of TPACK from participant surveys showed growth over time, the scores on the lesson plans created during the student teaching semester dipped slightly from the fall semester. It is important to note that although the mean scores dipped in the spring semester, the lessons did demonstrate adequate TPACK. The overall mean of the lessons in the spring semester was 2.91 on a 4-point scale. Essentially, the target for each dimension of the rubric was the 3-point (3.0) level. And although the decrease in mean scores from fall to spring was not significantly significant, it may be worth exploring. There are perhaps two ways to explain this "student teaching dip." First, for many students, full-time student teaching is stressful and sometimes almost overwhelming. This is often the first time that students are planning multiple lessons each day for weeks at a time. In the fall semester before student teaching, students have the luxury of drafting, editing, and revising a lesson for a course assignment. In the highly involved process of later student teaching, however, students are not able to invest as much time and energy into each individual lesson plan. It is also often difficult for student teachers to maintain what they have learned about pedagogy with the realities of classroom practice. Perhaps this slight regression is part of a larger and more systemic challenge that teacher education programs face in supporting student teachers in the field.

Another possible reason for this dip in lesson scores may be explained by the lesson-related scaffolding that students receive in their fall courses. Because many of the students choose to include the technology-infused lesson plan they create in the fall semester in their methods coursework, they often receive substantive feedback not only on the use of technology in the lesson, but also on the overall structure of the plan—particularly in terms of connecting the instructional strategies with the curriculum-content focus of the lesson. Two of the four methods instructors in this program typically conference individually with students on drafts of the lesson plans before they submit them. This type of scaffolding on individual lessons from either the cooperating teacher or university supervisor is often not possible during student teaching. It makes sense then that the quality of the teacher candidates' lesson plans would decrease somewhat during the student teaching semester, when they are left to their own devices.

Throughout all of the reflective statements, we noted a much higher percentage of codes related to TPK than any other knowledge domain. On the one hand, this would seem to indicate that the participants in this study focused primarily on TPK regarding technology integration. This finding is similar to previous research (Koh & Divaharan, 2011; Figg & Jaipal, 2009; Hofer & Harris, 2012). Although this is probably accurate to a certain extent, the survey responses and examination of the individual rows of the rubric (row 2 is a measure of TPK) do not seem to indicate any greater confidence or proclivity for TPK compared with TCK and TPACK. The striking difference in the number of statements coded with TPK may be more a result of the reflection prompts. These prompts asked students to describe an effective use of educational technology in their content area and to discuss when it is and is not appropriate to integrate technology in their teaching. These prompts are more general than the kinds of questions keyed to each domain in the survey and the content-focused nature of instructional planning. Although we would hope that, even with these general prompts, students would make more references to the importance of connecting technology use with the curriculum focus, the prompts were not worded in a way that would necessarily elicit this type of response. To more closely investigate participants' relative emphasis or reliance on TPK, the prompts could perhaps be more directed to more clearly elicit their thinking.

## Implications for Practice

TPACK development within a teacher preparation program is no doubt a complex endeavor where students may need to experience a range of learning opportunities to maximize their growth. Which experiences contribute to TPACK development and which experiences correspondingly detract from such development will be important information for program refinement. It will thus be important for faculty to carefully monitor and assess student growth as they move across a program, at various points and in a variety of ways, to get a reliable picture of the evolution of this important knowledge in teacher candidates. TPACK may also be a moving target, as aspects of technology, pedagogy, and content continue to change and evolve within the teaching profession and the body of educational research literature supporting it.

This study piloted a methodology for longitudinally examining TPACK across a three-semester master's in education initial licensure program in secondary education. By using four data points (summer, fall pre, fall post, spring) and three assessments (self-report surveys, lesson plans, and reflections), we attempted to construct a triangulated snapshot of TPACK development across the program. Within the context of this study, it appears that the methodology was useful for looking at TPACK development, and that there is the potential to further scale this approach across more students and a program of longer duration.

In fact, this study showed some remarkable consistency between the TPACK data sources used. Generally, the student self-report surveys on TPACK were quite similar in their results to the more objective measures related to the scoring of student lesson plans and lesson reflections. In a longer-duration program, such as a 4-year licensure design, there may well be an opportunity to expand a study's data sources to include additional assessments, such as teacher observations, content tests, curriculum products, and perhaps even case studies of individual students. With the rapidly changing context of technology today, some of these assessments may even be able to be automated or embedded within a teacher preparation program to provide a more rapid and periodic glimpse of TPACK development that is aligned with its courses and experiences. Understanding how technology integration knowledge develops within a specific teacher preparation program will no doubt be a critical planning component for effectively preparing students for an increasingly technology-infused workplace.

The study also reinforced that the various elements of TPACK (such as TPK and TCK) do not necessarily develop at the same time and in the same way. Such results would suggest that it will be important to look at TPACK development within teacher preparation coursework that occurs in arts and sciences content courses as well as in education and methods courses. Teacher preparation programs are typically educational "mosaics" with a variety of courses, student experiences, and instructional support mechanisms brought to bear on a student's targeted development into an effective teacher. Within such a program mosaic, it is obvious that TPACK should be examined in a variety of ways and at various points within a program to be truly useful for program refinement.

Each individual TPACK assessment may also have its limitations. For example, self-report surveys may be prone to student under- or over-reporting, and lessons plans may not provide enough detail to examine TPACK. Student reflections may also be unfocused or difficult to interpret. However, this study suggests that a research methodology combining several data sources and looking for patterns across key time periods in a program is promising for glimpsing the picture of TPACK development as it evolves within students.

### Limitations of the Study

This study is limited in two primary ways: the small sample size and the focus restricted to the scope of the teacher education program. The small sample size is due primarily to the challenges of data collection in a longitudinal design. Although we had low attrition between semesters, collecting a complete data set for all the participants was a challenge due to schedule conflicts, volume of data, competing demands on student time, etc. The decision to include only two students in each content area was deliberate to ensure a balanced representation across content areas and complete data sets within the analysis group.

The second limitation of the study deals with scope. The duration of the study was limited to the three semesters of the teacher education program. Significant TPACK development undoubtedly occurs in the first several years of full-time teaching practice. If studies can span both the teacher education program and the induction years, the results would significantly inform our understanding of how TPACK develops over time.

## Recommendations for Future Research

As described at the beginning of the article, the effective integration of technology in K–12 schools is an increasing priority. As educational technology tools and resources continue to evolve, new instructional opportunities arise. Yet any tool is only as good as the user's knowledge to operate, and more important, to integrate that tool to help students master learning objectives. In the case of preservice teachers' technology integration, it is increasingly apparent to researchers that such technology integration may require a relatively sophisticated and interrelated understanding of the technology, pedagogy, and content of their instruction, resident within the TPACK construct and supported by a strong teacher preparation program. Sophisticated knowledge such as TPACK may well require a very systematic approach to understanding and supporting students' knowledge development. In today's rapidly paced and increasingly technical world, we cannot afford to leave any K–12 student's potential untapped by a teacher preparation program that is unable to provide each teacher with the technology-related knowledge they need to effectively reach their students.

To better understand this knowledge development, more longitudinal studies are required. Triangulated study designs that include both self-report and performance measures that span multiple years in the field will help us to not only better understand how TPACK develops, but also know what contextual factors support and inhibit this growth. Through a distributed, systemic effort to study teachers' knowledge development for technology integration, we will better understand how to nurture, support, and sustain this important growth area in classroom teachers.

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