Exploring TPACK Model Practices: Designing, Facilitating, and Evaluating Effectiveness of Technology Experiences Among Pre-service Teachers

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Introduction

In the midst of ubiquitous technology use to support communicative and professional pursuits, there is evidence that the potential for digital tools to facilitate teaching and learning in K-16 classrooms has not been widely realized (Bauer & Kenton, 2005; Project Tomorrow, 2009). There is a growing number of scholars calling not only for technology use in classrooms, but for pointed capitalization of available digital tools to help transform classrooms toward spaces more pedagogically and epistemologically dynamic, collaborative, and student-centered (Belland, 2009; Ertmer & Ottenbreit-Leftwich, 2010; Leander, 2007). Pre-service teacher education has a role to play in shifting the paradigm and addressing deficits in classroom technology integration. This role is best assumed through facilitation of knowledge construction in pre-service educators at the intersections of technology, pedagogy, and content (Mishra & Koehler, 2006).

This study examined the potential for increasing Technology, Pedagogy, and Content Knowledge (TPACK) development among pre-service teachers within one teacher education program. More specifically, this work first examined pre-service teacher perceptions, beliefs, and attitudes about technology, then evaluated the effectiveness of researcher-crafted course experiences designed to foster specific technological skill sets that intersected with pedagogical practices framed by student-centered and collaborative knowledge construction.

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In addition, a qualitative case approach was used to supplement existing quantitative data through interviews and classroom observation of three former students, who exhibited well-developed and sophisticated TPACK practices, honing in on one practicing teacher in her elementary classroom setting. Through this examination, the work contributes to the growing collective voice calling for a transformation of education, one that uses the affordances of digital technologies, in addition to the myriad of other tools, to recreate learning spaces that empower students to be *participatory citizens* prepared for twenty-first century landscapes (Jenkins, Purushotma, Weigel, Clinton, & Robison, 2009). Specifically, we used Web 2.0 tools (i.e., blogs and microblogs, wikis, photo and video publishing sites, social networking sites, and information RSS aggregators) to encourage students to assume roles of active creators of content, critical consumers of information, and creative and collaborative problem-solvers.

Theoretical Framework

This work emerged from multiple theoretical crossroads. First, the design built heavily on our understanding of New Literacy Studies (Coiro, Knobel, Lankshear, & Leu, 2008; Lankshear & Knobel, 2003; Pahl & Rowsell, 2005), namely, as it applies to classroom pedagogy by broadening the scope of "*literacy*" and "*text*" to include the ever-increasing digital milieu of twenty-first century communication. These broadenings within New Literacy Studies (NLS) overlap with a theoretical focus on multimodality (Hull & Nelson, 2005; Jewitt & Kress, 2003; Kress & van Leeuwen, 2001; Pahl & Rowsell, 2005), one that highlights different ways that various modes (written alphabetic text, audio, still and moving imagery, and the combinations of each) function in our understandings and practices of literacy in the present digital age. With these underpinnings informing our work, along with the overarching theoretical frame that knowledge is socially constructed (Vygotsky, 1978), we ultimately found complimentarity with educational technology researchers working through various methodologies to highlight the value of inquiry aimed at the intersections of technology, pedagogy, and content knowledge (Chai, Koh, & Tsai, 2010; Koehler & Mishra, 2005; Koh & Divaharan, 2011; Mishra, Koehler, & Henriksen, 2011). However, we understand that our leanings toward social constructivism do not equate to "good" TPACK development; rather, it reflects our philosophical and pedagogical framework within this study.

Finally, this work is built both on qualitative and quantitative methodological studies that also employed Mishra and Koehler's (2006) TPACK framework, allowing us to better theorize a mixed methodology that "*invites us to participate in dialogue about multiple ways of seeing and hearing, multiple ways of making sense of the social world, and multiple standpoints on what is important and has to be valued*" (Greene in Creswell & Clark, 2011, p. 4). In turn, we include data oriented toward an *instrumental case approach* (Creswell, 2007; Stake, 2005), one that allows us to pursue a critical reflection of our own teaching practices and course

designs, and how that process of reflexivity might inform the design of future course facilitation. The use of the term *design* is of no small consequence for us, just as our brief note about incorporating case methodology is no small theoretical component within our work, and we owe, at least in part, the promising conceptualization of *design-thinking* (Brown, 2009) for education, particularly as we believe the term "*design*" carries much weight in models of TPACK.

Paramount to our project is a direct intent for us to practice, play, and reflect on our own teaching, while designing, facilitating, and evaluating course experiences intended to foster Technological Pedagogical Content Knowledge (TPACK) in pre-service teacher education candidates. This process of iteration is for us a necessity for innovative and creative pedagogy, one that informs a more comprehensive approach to evaluating TPACK development among undergraduates.

TPACK: Synthesizing Technology, Pedagogy, and Content Knowledge

TPACK is a cornerstone of current research examining technology integration at post-secondary levels, providing pre-service teachers with opportunities to capitalize on affordances through multiple technologies for teaching and learning. Mishra and Koehler (2006) urged scholars and practitioners to expand the ways teacher technology knowledge is viewed, maintaining that standalone educational technology courses are not sufficient to parlay into meaningful technological innovation in the K-12 classroom. Rather, Mishra and Koehler (2006) posited that seamless integration will not occur, unless teachers develop a complex and situated knowledge that brings together three different types of knowledge—content, pedagogical, and technological knowledge.

It is only through the development of these three overlapping areas of expertise that educators will effectively utilize technology for teaching and learning in a manner that transcends "*low level*" practices with technology that are too commonly typified by teacher-directed presentations of information, or utilization of computer software, simply for administrative, or non-pedagogical, communicative purposes. Mishra and Koehler (2006) conceptualize necessary teacher knowledge as a combination of these three areas of understanding, refuting the notion that technology skills should be considered separate from pedagogy and content knowledge. They thus extended the previous work of Shulman (1986), who highlighted the overlap between pedagogical knowledge and content area knowledge as pedagogical content knowledge (PCK). The three types of knowledge culminate through "*complex interplay*" (Mishra & Koehler, 2006, p. 1025) into TPACK, often through intuitive and nuanced understandings of ways content expertise, pedagogical practices, and technology integration intersect. This theoretical framework, depicted in Fig. 1, is the conceptual lens through which we designed, facilitated, and evaluated pre-service course technology experiences, aimed at fostering teaching practices in line with effective K-12 technology integration.

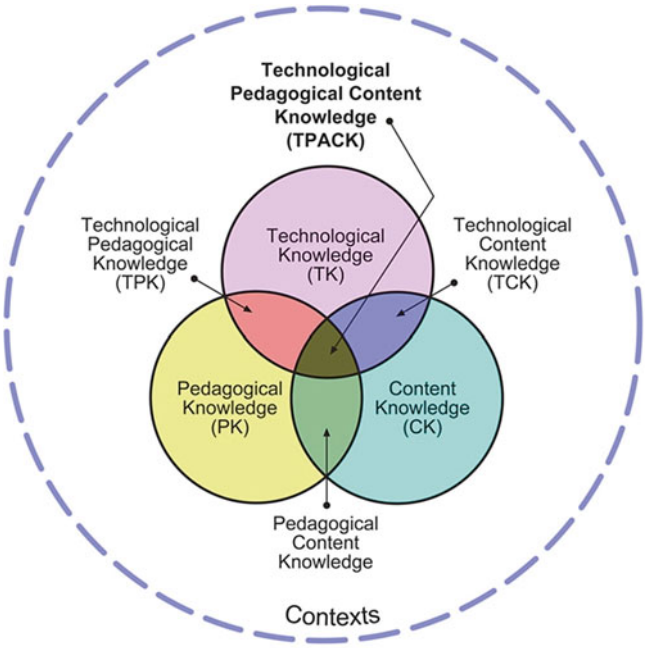

Fig. 1 TPACK framework (Adapted from www.tpack.org)

From Mishra and Koehler's (2006) work, emerging research has examined various course experiences aimed specifically at increasing pre-service teachers' TPACK development. For example, research has demonstrated significant gains in TPACK, when course experiences included *design* activities, or when Instructional Technology courses were facilitated to teach future teachers both about technology tools *and* about how to teach effectively with those tools (Chai et al., 2010). Likewise, Shin et al. (2009) utilized a pre/post-test design to examine the effectiveness of an instructional technology course sequence, designed to "*expose teachers to ideas and skills from educational technology in the context of theories of learning and development*" (p. 4152), arguing about how specific course experiences worked directly to help increase participants' level of TPACK overall.

Coupled with these examples is the argument that teacher candidates are consistently lacking exposure to learning experiences in their pre-service programs that support development of skills necessary to integrate technology for teaching and learning in meaningful ways (Ertmer, 2005; Kay, 2006). Not only do pre-service teachers lack modeled use of technology-enhanced instructional activities, but candidates also have inadequate opportunities to design collaborative learning activities, combining the affordances of various technology tools with specific learning objectives (Gotkas, Yildirim, & Yildirim, 2009). Addressing this increasingly documented gap in teacher education programs, we found helpful as a starting point

Kay's (2006) literature review identifying effective strategies for integration of technology into teacher education programs (i.e., providing mini-workshops, infusing technology into all courses, use of multimedia, facilitating collaborative design opportunities, and providing hands-on practice in field settings). The programs that proved most successful in affecting change in attitude, ability, and use were those that engaged in four or more identified strategies. Kay (2006) challenged researchers to delve more comprehensively into multiple forces at play, when considering effective technology integration together with pedagogy and content.

Research Questions

This study was guided by the following research questions:

1. How do pre-service teacher candidates view the role of technology across multiple contexts (K-12 classrooms, university courses, personal spaces)?
2. In what ways along a spectrum of readiness are pre-service teacher candidates prepared to integrate technology into K-12 classrooms, namely, in ways that foster student-centered and collaborative learning?
3. What insight might be gained about technology integration from case-oriented interviews and classroom observations of practicing teachers, specifically those who completed teacher preparatory courses designed with TELs?
4. How might we evaluate the effectiveness of our technology-enhanced course designs [i.e., the facilitation of "Technology Enhanced Lessons" (TELs)] to increase the depth of pre-service candidate understanding of TPACK?

Methodology

Our work is best described in three phases—each informing and in some cases redefining subsequent research questions. Phase one, for example, consisted of qualitative data via survey questions aimed at pre-service teacher candidates' perceptions of technology; at the ways digital tools function in their experiences in K-12 settings, in their university courses, and in their personal lives; and at their self-efficacy and self-reported comfort levels with technology. Our second phase of research included follow-up observations and interviews with candidates, who participated in the initial data gathering, yet presented strikingly mature anomalies within their narrative discourse, namely when asked to articulate notions and uses of technology in K-12 spaces. The third and final phases were informed by issues raised through our qualitative analysis and quantified pre/post-test measurements, aimed at evaluating statistically the impact of specific instructional practices on participants' depth of understanding regarding TPACK.

Phase I: Exploring Technology and Literacy Practices in Multiple Learning Spaces

During the course of two semesters, we surveyed approximately 40 undergraduate seniors in an elementary education program regarding their perceptions and attitudes about using "*technology*" for their future teaching and in their personal lives. Using Lankshear and Knobel's (2007) paradigm of "*new literacies*," we analyzed data for words and descriptions that are indicative of the values and priorities of new literacies, shaped by two major components—new digital technologies and a focus on *new ethos stuff*, evidenced primarily through terms and phrases suggesting collaboration, distributed authority, collective knowledge production, innovation and creative problem-solving. Initially, we sought evidence linked to what Lankshear and Knobel (2007) term a "*cyberspatial-postindustrial*" mindset, exemplified most readily by the participatory content production, created with Web 2.0 tools and social networking websites.

Our initial analysis work, however, provided little to substantiate the supposition that pre-service teacher candidates viewed technology as transformative pedagogical tools capable of fostering collaborative knowledge construction in classroom settings. Rather, the tools were situated within their narrative responses predominantly as a means to foster student interest and increase motivation. Perhaps the most predominant theme throughout our data during phase one involved the notion that technology, in and of itself, is an inherently good thing for teaching and learning. It "*makes learning more engaging;*" it is "*vital for our times;*" it "*makes learning fun*." These comments speak to a powerful grand narrative that positions technology as something more conceptually singular than the myriad of tools and practices that might occur in various educational contexts. What became disconcerting for us appeared to be a disconnect between positive statements about technology use in learning environments and an ability to articulate specific examples of how technology had in fact functioned during their own preparatory learning for future teaching. The role of pre-service teacher candidates, along with beliefs about pedagogy and technology integration in K-12 classrooms, seemed to be defined through participant narratives about learners as recipients of knowledge rather than collaborators and active participants in knowledge co-construction.

However, as we delved deeper through questions about the use of technology, we discovered the term *technology* to be both multifarious and loaded, depending on its context. For example, in both survey and interview data, undergraduates defined the use of technology in the elementary education program and in public school classroom practicum experiences through specific tools, namely, interactive whiteboards and software, such as, Microsoft Word and PowerPoint. What resonated consistently involved the distinction pre-service students made between tools for pedagogical purposes in their university courses and elementary classroom experiences (i.e., PowerPoint and interactive whiteboards) and the use of "*daily life*" tools (i.e., text messaging via cell phones and social networking through sites, such as FaceBook). Interestingly, the "*daily life*" tools often functioned to help navigate

successfully their academic responsibilities by organizing and communicating with one another:

> Last semester, we set up a FaceBook page, so if there's an assignment, then someone will post something. That way we are all on the same page. It's been helpful for me. Each of us can modify and there are about 20 of us. It has been a really good tool, so you can address the entire class. A lot of times, we also send mass text to everyone. Everyone has everyone else's number.

This distinction seemed to occur when thinking about technology tools as (1) those that are incorporated into classroom learning by university faculty or by public school mentor teachers and (2) those that are incorporated into learning practices specifically by students.

Ultimately, three learning spaces—personal lives, university academic settings, and public school classrooms—emerged as predominant, regarding the use of technology tools as a means for teaching, learning and, more generally, for socializing. Overlaps concerning similar literacy practices associated with various technology tools occurred among the three spaces and, likewise, noticeable gaps stood out in the data when comparing each of the three learning spaces. Through these overlaps and gaps, we gained insight about ways we might integrate technology across these spaces to further weave personal knowledge concerning literacy and technology practices into creative and effective pedagogical practices.

Teaching with Technology and/or Teaching About Teaching with Technology

When prompted, it became evident that many of our undergraduates agreed that various tools provided specific affordances for teaching and learning. For example, when asking students about engaging young learners through interactive whiteboards and Internet resources, we found a high frequency of comments noting the ability to "*break free from textbooks and experience things more realistically*." Likewise, a consistency within responses highlighted beliefs that educators can use technology to "*differentiate*" for "*visual learners*" by interspersing content with images, phrases harkening back to a still prevalent discourse surrounding Gardner's (1983) theory of multiple intelligences. This continues to raise questions about what and how to teach, particularly in light of multimodal theories applied to education (Hull & Nelson, 2005; Jewitt & Kress, 2003; Kress & van Leeuwen, 2001) and the diverse offerings of new digital technologies. For example, reading alphabetic text is in and of itself a practice of "*visual learning*," yet one that is modally different from the visual process involved while viewing still images, which presents all information simultaneously rather than in alphabetic and therefore sequential order (Kress & van Leeuwen, 2006). This has implications for twenty-first century educators who seek to challenge learners to grow as active, critical consumers of an increasingly visual milieu of digital information. Likewise, add speakers and the affordance of auditory representation is gained; moving images (movies) offer an even more sophisticated combination of skills across the various epistemological modes of constructing knowledge.

The concept of differentiating using tools, such as LCD projectors and interactive whiteboards, to facilitate learning with the use of images is indeed a pedagogical affordance associated with these tools. Likewise, comments about using interactive whiteboards and websites, such as http://www.brainpop.com, to "*make it more fun, because kids could get up and touch it and play with it*" speak indirectly to multimodal affordances. Our inquiry soon focused on whether our pre-service undergraduates were simply learning *about* certain technology tools (and if so, which ones and why), or whether they were also explicitly learning *how to choose and teach purposefully* from among a variety of technology tools, particularly ones capable of fostering opportunities for collaborative and participatory knowledge construction. In one sense, we shared excitement about the enthusiasm for using technology from participants in phase one of our qualitative work. On the other hand, we questioned the pedagogical beliefs coinciding with technology integration—pedagogical beliefs being arguably most central to facilitating "*high-level*" classroom technology uses in line with constructivist beliefs (Ertmer & Ottenbreit-Leftwich, 2010; Judson, 2006).

Phase II—Incorporating Instrumental Case Study Methodology

Of the approximately 40 pre-service teachers we surveyed in phase one, we chose three participants to interview, selected specifically for their written responses, which served as striking anomalies to survey questions, when compared to descriptions by their peers, indicating beliefs more in line with transformative uses of technology to facilitate collaborative and student-centered pedagogical practices. In a follow-up interview, one of the three participants spoke about experiences teaching in a setting that valued types of computer use with students, counter to teacher-led PowerPoints, or instructor-driven whiteboard flipchart lessons:

> We use their [students] laptops for research. I will give them a topic or a question and have them research. I've had a lot of conversations with my kids about credible sources and what to steer away from online. We talk about how to tell if a website is a valuable place to look for information. And then, I leave it up to them to use their laptops to conduct their research. The times with their computer are probably more student-led than other times of the day.

Building, therefore, on research that brings into question data solely self-reported about relationships between teacher technology integration practices and pedagogical beliefs (Bai & Ertmer, 2008; Judson, 2006) and the call for researchers to further address an absence in the literature of direct classroom observations (Polly, Mims, Shepherd, & Inan, 2010), we followed one student after graduation into her first teaching assignment to observe classroom practice, and to continue collecting formal and informal interview data. Though localized, highly contextual data, it proved insightful when considering pre-service transitions into classroom teaching and, following Ertmer and Ottenbreit-Leftwich's (2010) work, how school culture functions in fostering technology integration and how self-efficacy among new

teachers emerges surrounding technology use. These focal points coincided with our phase three data, which speak to the effectiveness of "*Technology Enhanced Lessons*" (TELs) to increase TPACK development among our undergraduates.

In observations and conversations with our case participant Margaret (pseudonym) in her first year of teaching, we observed an innovative and effective use of technology integration. Specifically, though Margaret stated that she found the learning curve for capitalizing on the potential of her classroom interactive whiteboard technology rather steep, she exemplified a student-centered pedagogical approach by facilitating other technologies, in one instance student blogs, in which she taught her students explicitly the affordances of the technology—the capacity to share writing in progress, to choose and publish "*best*" pieces, and to receive peer feedback online—while also focusing on specific learning objectives (to practice and improve writing processes and grammar skills). Margaret followed her students' blog enthusiasm with a culminating event, a mock coffee house sharing in which Margaret and a fellow teacher dressed the role of coffee house baristas, bringing lamps to emulate real coffee house mood lighting, requiring students to choose favorite pieces to share, opening the classroom doors during a school day morning for parents to visit, and ultimately, reflecting on the experiences together.

About teaching the use of blogs in school and the potential barriers teachers face when using this type of Web 2.0 tool, Margaret stated, "*We have it to where only the kids in the school can become a follower and view the blogs—well, outside people can come to view them, but they cannot edit or comment.*" The purposeful (and careful) use of blogs, the sharing of classroom learning and artifacts, and the opening up of her classroom to "*outsiders*" is no coincidence; rather, the cultural atmosphere of learning within the school, a "*vision shared*" among faculty and administrators, encouraged this type of pedagogical iteration, a modeling of risk-taking and subsequent reflection that highlighted parallels between decisions during the craft of teaching and student choices during learning processes. Though notably an isolated event to celebrate as teacher educators, these observations inspired our own creative spirits for technology integration in our elementary education program. As researchers, it raises a complex question, not unlike inquiries regarding "*school readiness*" and other indicators of academic success—What forces are at play, when considering the wide spectrum of TPACK efficacy among new teachers?

Phase III—Evaluating TPACK Through "Technology-Enhanced Learning" Experiences

Our phase three quantitative design drew from existing work, namely, Chai et al.'s (2010) use of "*technology enhanced lessons* (TELs)" (p. 66) in which pre-service teachers learn about affordances and limitations of technology tools and pedagogical applications, and Schmidt et al.'s (2009) development and validation of an assessment instrument regarding TPACK development among pre-service teachers. Our research included course experiences for pre-service teachers that model

and provide exposure to various uses of technology for content learning and offer opportunities to practice and design lessons with digital tools. Specifically, these course experiences incorporated digital tools and included the following:

1. Developing an overarching social networking website (http://www.ning.com), allowing participants to create and share individual webpages, music, photos, and blog post reflections on course topics.
2. Blogging to articulate written critical reflections, receive peer feedback, and foster classroom dialogue on specific course content topics.
3. Choosing from a variety of digital tools (i.e., online video streaming resources, mobile devices, such as cell phones, coupled with software or websites for informal assessment and real time polling (http://www.pollanywhere.com), and multimedia production of texts via CAST's UDL (Universal Design for Learning) or Book Builder website (http://bookbuilder.cast.org), to model epistemologically diverse uses of technology during student lesson planning.
4. Utilizing online interactive resources through the IRIS Center (http://iris.peabody.vanderbilt.edu) and Vanderbilt's comprehensive website for education of students with disabilities.
5. Collaborating on the input of wiki content, specifically regarding instruction for diverse learners (i.e., collectively creating an educator UDL checklist).

The threads that connected the narratives of our pre-service candidates were promising—students expressed excitement about the affordances of various technology tools and shared nimble use regarding their own personal and academic pursuits. However, we found less evidence of direct intersections between technological, pedagogical, and content knowledge (TPACK). The majority of the candidates did not describe technology as tools capable of shifting classroom dynamics from teacher as expert and purveyor of information to teacher as collaborator and facilitator of knowledge construction.

This emerging theme guided the redesign of an existing course in the education program, the components of which were designed intentionally to reinforce course learning objectives and to encourage discovery of preexisting, albeit latent potential apparent in the candidates' use of technology for personal and academic pursuits. By design, the course instructor, a member of the research team, modeled a variety of digital tools to teach the content of the course, challenging participants to wrestle with and reflect upon the potential for those tools in K-12 spaces.

In order to measure the effectiveness of these course experiences on participants' level of TPACK, we measured pre- and post-test administrations of the Survey of Pre-service Teachers' Knowledge of Teaching and Technology (Schmidt et al., 2009). Students accessed this 147-item self-report survey the first week of the course, then again after 8 weeks of the course TEL experiences. The instrument, appealing for its previously determined internal consistency reliability (Schmidt et al., 2009), assessed student knowledge through the division of seven TPACK subscales: Technology Knowledge (TK), Content Knowledge (CK), Pedagogical Knowledge (PK), along with the more refined combinations of PCK, TCK, TPK, and ultimately, TPACK.

Technology-Enhanced Lessons (TELs)

From our beliefs embracing New Literacy Studies (Lankshear & Knobel, 2007), our conceptualization of TPACK as a nuanced and complex model of intersecting knowledges, and Chai et al.'s (2010) TEL approach for increasing TPACK development among pre-service teachers, a productive model emerged for us from which to design course experiences. In line with new ethos thinking, TELs used digital tools that allowed students to participate in collaborative knowledge construction. The intent behind the design was threefold: (a) *to expose* students to a variety of tools that can be integrated into K-12 classrooms with diverse learning needs; (b) *to model* integration of tools in order to explicitly teach course content (in this case special education methods), and (c) to provide opportunities *to design* activities using digital tools, fostering opportunities to experience and reflect on student-centered learning practices.

Findings

Valuable Technological Knowledge in Contexts Beyond School Rarely Translated into TPACK

Open-ended survey responses and one-to-one interviews yielded a nuanced picture of the plethora of ways that pre-service teachers in one education program experienced and perceived technology across multiple spaces. Pre-service teachers discussed a myriad of uses of tools interwoven in their personal lives—FaceBook groups to collectively organize, inform, and adhere to deadlines regarding school coursework (a strikingly powerful community building practice among cohorts); the ability to connect and share with family and friends beyond school settings through various social networking sites; and the capacity for information gathering through tools, including online search engines, GPS and mapping sites accessed via computer or mobile device; and the ability to receive status updates about friends and family, or news and entertainment. Despite these descriptions of agile uses in personal and academic spaces, and the perception that technology could engage and motivate students, there were few responses that alluded to a deeper understanding of the potential role of technology in fostering collaboration and student-centered learning. Few of the terms associated with "*new literacies*" were reflected in discussions, and little evidence existed to substantiate the supposition that technology can be a transformative pedagogical tool capable of empowering students to dialogue, produce content, and co-construct knowledge. Rather the tools were situated solely as a means to foster student interest and maintain motivation.

Stand-Alone Technology Courses Functioned Little to Impact TPACK Development

Comments gathered and analyzed during phase one highlighted a discrepancy between student experiences in terms of the value they attributed to a single required technology course for our education majors. For some, the material was "*very easy*," "*more of a review of the technology I already used*." Others "*learned a great deal*," or perhaps more poignantly stated, "*felt like everyone in the class was on different levels of understanding*." What seemed to define the worth of the course, when analyzing participant responses, hinged on how much of the information presented was novel and how much coincided with participants' prior technological knowledge. Not surprisingly, students self-reporting a preexisting degree of adeptness with the tools incorporated in the course curriculum (blogs, for example) represented the course expectations as review.

The collective narrative that emerged regarding learning experiences in one stand-alone technology course speaks loudly of the lack of TPACK development as a "*trans-disciplinary*" responsibility (Mishra et al., 2011) throughout the program holistically, a responsibility that requires content and methods instructors to "*repurpose*" digital technologies for complex and contextual interplays between content, technology, and pedagogy. We found the lack of evidence supporting connections between the tools taught in a stand-alone course, and how they could be used pedagogically for teaching and learning in the K-12 classroom, a call to further examine, as researchers and pre-service education faculty, our own classroom practices and the potential for TPACK development to increase.

Technology-Enhanced Lesson (TEL) Participants Showed an Increased Level of TPACK

Our conversations with pre-service candidates consistently paralleled other researcher critiques lamenting the overall ineffectiveness of standalone instructional technology courses (Groth, Dunlap, & Kidd, 2007; Mishra et al., 2011). It was apparent that although candidates assigned different values to the technology course, whatever gains in technological knowledge occurred was translated little toward the development of a more complex understanding of how TK interplays with content and pedagogical knowledge. More promising methods of teaching candidates about and with technology include course designs that *model* student-centered technology practices, while teaching content, and that integrate opportunities for candidates to practice designing with digital tools. In order to evaluate the effectiveness for increasing TPACK development among pre-service teachers, a MANOVA compared the mean for each TPACK subscale on pre- and post-test results, regarding specifically student experiences with course TELs. The results indicated a significant difference between scores on the pre- and post-test

Table 1 Pre- and post-test means and standard deviations for subscales

Subscale	Time	Mean	Standard deviation	*N*
TK	1	3.59	0.81	66
	2	3.68	0.59	68
CK	1	3.68	0.49	68
	2	3.85	0.49	68
PK	1	3.74	0.59	68
	2	4.01	0.41	68
PCK	1	3.39	0.65	66
	2	3.80	0.51	68
TCK	1	3.31	0.77	66
	2	3.89	0.76	68
TPK	1	3.86	0.76	66
	2	4.22	0.47	68
TPACK	1	3.65	0.63	66
	2	3.97	0.48	68

scores on the pedagogical knowledge subscale, $F(1, 132) = 10.04$, $p = 0.002$, $\eta^2 = 0.071$; the PCK subscale, $F(1, 132) = 16.76$, $p < 0.001$, $\eta^2 = 0.113$; the technological content subscale, $F(1, 132) = 23.51$, $p < 0.001$, $\eta^2 = 0.151$; the technological pedagogical knowledge scale, $F(1, 132) = 11.03$, $p = 0.001$, $\eta^2 = 0.078$; and the technological pedagogical content subscale, $F(1, 132) = 10.90$, $p = 0.001$, $\eta^2 = 0.076$. The means and standard deviations for each subscale are presented in Table 1.

TEL participants did not demonstrate a significant growth in technology knowledge (TK), as a result of participation in the course, but this did not prevent the skills measured by the other subscales from showing significant increase. We find validity in the possibility that these participants were in fact already "*literate*" with multiple technologies, and subsequently, repurposed this knowledge in academic contexts, resulting in the insignificant TK scores. In addition, the lack of TK increase could be attributable to the course design, one focusing on special education rather than on educational technology. Similarly, there was not a significant increase in content knowledge (CK), an anticipated result, considering that the content of the course did not deal with specific content-area information or instruction germane to a single content subject area. More credence surrounded the practice of instructor modeling tools for teaching special education content, opposed to course time spent learning the tools for specific content-area purposes.

Discussion

Our findings reiterate existing work that reports ineffectiveness of standalone technology courses, as sole means for adequately preparing pre-service teachers (Choy, Wong, & Gao, 2009). Modeling effective technology use for pedagogically sound instruction (Bai & Ertmer, 2008) and integrating technology in content area courses

(Judge & O'Bannon, 2008) are promising approaches for preparing pre-service teachers. Our research furthers notions that TPACK development *throughout* pre-service education programs is achievable. Within our data sets, the significance of change between pre- and post-test scores on six of the eight subscales demonstrated that concerted efforts through TELs for collaborative and participatory learning likely contribute to increased TPACK scores for pre-service teachers. TELs, as we conceptualize them, can be integrated into any course throughout education preparatory sequences. We are further encouraged that within 8 weeks, with the exception of scores on the technology and content knowledge subscales, our data show significant increase in TPACK skills, as measured by the survey for participants in the course. The non-significant subscale findings are noteworthy, however, reminding us that the TPACK framework "*offers no specific directives about what content to teach … which pedagogical approaches are useful…and what kinds of technologies to use*" (Mishra et al., 2011, p. 24). Therefore, our TELs represent a contextual approach, notably one that relies on a constructivist theoretical framework, to apply understandings of TPACK development through specific course designs; it is ultimately valuable for programs to evaluate and tailor TPACK developmental needs in content area courses to best fit the efficacy of those pre-service teachers.

This and other work examining the impact of course experiences on TPACK indicate a growing body of literature that speaks directly to teacher education program design and practice.

Further work is needed to examine and discern instructional practices that are effective in pre-service education programs in transforming course experiences to better address TPACK development. The disconnect between what teachers believe about teaching and how they actually teach is a thread in the multifaceted public discourse about how to best reform education. Futrell (2010) perhaps questioned best, "*Do we want to reform or transform our system of education*?" (p. 432), transformation defined as change that enables the system to accomplish new things, whereas reform tweaks an existing system to improve performance of existing operations. We are encouraged by our data—we view the affordances of various digital tools and opportunities for more participatory course experiences as a means to increase pre-service teacher TPACK, a development we deem necessary to *transform* twenty-first century K-16 education. The integration of carefully designed course experiences contributes to the momentum of examining purposeful practices at all levels of the K-16 educational system, a worthy endeavor in light of much noted adherence to traditional modes of instruction and "*low leve*l" technology use.

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