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Curriculum Design for Technology Infusion: A Continuous Collaborative Process

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In this article, the authors discuss technology integration curriculum in teacher preparation programs, focusing on key elements of both the curriculum and curriculum development process. Specifically, they highlight the need to develop a coherent teacher preparation program founded on shared values and practices and responsive to change. When considering technology in the teacher preparation curriculum, this means integrating technology content and practices throughout the program. Research is discussed on the efficacy of touchpoints, or opportunities for integrating technology in the teacher preparation curriculum, including technology-focused and subject-specific courses and opportunities for practicing teaching with technology in field experiences. Finally, key elements of a technology infusion approach are highlighted and program design incorporating a continuous, collaborative process is suggested to support ongoing improvements to effective technology infusion.

This article is one of four articles in an invited special issue co-edited by Kevin J. Graziano, Teresa S. Foulger, and Arlene C. Borthwick that presents research-based design recommendations on the four pillars of a technology-infused teacher preparation program: (a) technology integration curriculum, (b) modeled experiences, (c) practice with reflection, and (d) technology self-efficacy. These pillars are essential components that work together to support successful program-deep and program-wide technology preparation.

Preparing teacher candidates to utilize digital technologies effectively in their future teaching should be a central goal of teacher preparation programs (Krumsvik et al., 2013). However, integrating technology into teacher education can be challenging because of the rapid pace of technological change (Ottenbreit-Leftwich et al., 2010) as well as the importance of connecting technology to content areas (Mishra & Koehler, 2006). As a result, educational technology scholars promote a technology curriculum that spans multiple courses, instructors, and clinical experiences (for example, Clausen, 2022; Collier et al., 2004; Foulger et al., 2017; Levin, 1994; U.S. Department of Education, 2017), but designing a comprehensive curriculum can be challenging. This article addresses the first pillar of technology infusion — technology integration curriculum — by exploring the parts and processes of curricular design.

There is little disagreement about the need to apply national technology standards and competencies for teacher candidates when designing the teacher education curriculum. In doing so, care must be taken to ensure the resulting program-wide curriculum is not disjointed or fragmented but illustrates coherence, or “the degree to which central ideas regarding teaching and learning are shared by all individuals involved in educating teachers and the degree to which learning opportunities are organized both conceptually and logistically toward those goals” (Grossman et al., 2008, p. 274; see also Tatto, 1996).

Teacher educators and candidates experience coherency when theory and practice are purposefully connected and a faculty member presents a shared vision of teaching and learning (i.e., conceptual coherency, see Hammerness, 2006). Teacher educators can also promote coherence through the structure of the curricular program, including the organization and alignment of courses and other learning opportunities.

Programs with strong coherence are deliberately sequenced and include courses that intersect with each other and with field experiences (Darling-Hammond, 2006; Heggen et al., 2014). Faculty members, including those across university divisions, collaborate with one another and present a unified vision of core ideas, frameworks, and professional norms (see also Tatto, 1996).

Researchers have demonstrated that coherent teacher preparation programs positively impact learning outcomes (Fortus & Krajcik, 2012; McQuillan et al., 2012). For example, compared to programs that demonstrate limited coherence, programs with a high level of coherence have a greater impact on teacher candidates’ initial conceptions and practices (Darling-Hammond et al., 2005; Tatto, 1996) as well as produce graduates that are better prepared for work in schools (Darling-Hammond et al., 2000; Koppich & Merseth, 2000; Zeichner et al., 2000).

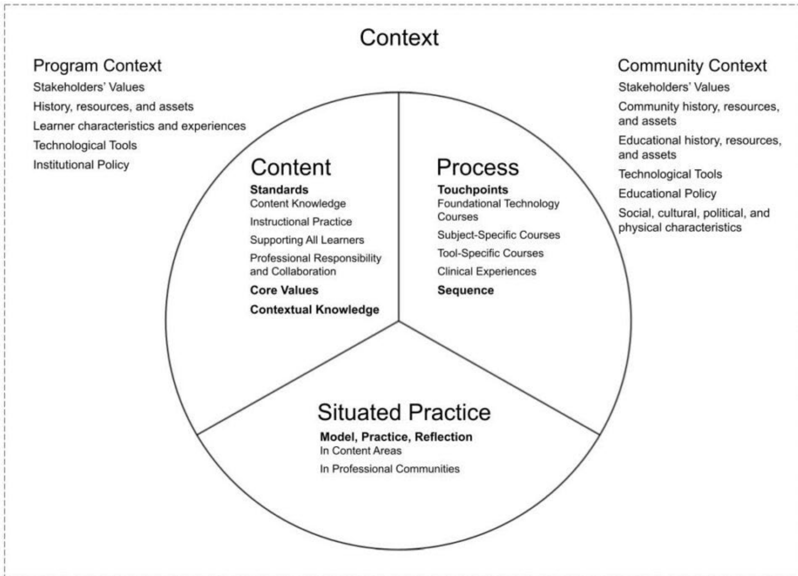
Teacher educators have emphasized that an important area of focus for coherence in teacher preparation is the connection between pedagogy and content (Canrinus et al., 2019; Darling-Hammond, 2006). For example, Darling-Hammond described that in coherent programs, "subject matter learning is brought together with content pedagogy through courses that treat them together" (p. 306). The integration of content and pedagogy reflects Shulman's (1987) construct of pedagogical content knowledge (PCK); successful teachers not only have knowledge of the content they teach and pedagogical theories and approaches, but they also have an integrated knowledge of content and pedagogy.

Mishra and Koehler (2006) extended PCK to include technological knowledge, resulting in technological pedagogical content knowledge (TPCK; later revised to technology, pedagogy, and content knowledge [TPACK]). TPACK emphasizes the need for teachers to integrate content, pedagogy, and technology within a context. Original descriptions of context included subject matter, grade level, available technologies, and student backgrounds (Koehler & Mishra, 2005; Rosenberg & Koehler, 2015). Scholars have also included classroom and institutional conditions for learning, situated teaching activities, and the epistemological beliefs of teachers as important pieces of context (Porras-Hernández & Salinas-Amescua, 2013).

In 2019, Mishra suggested an additional construct called "contextual knowledge" (XK), describing context as a knowledge domain akin to pedagogy, content, and technology. Thus, to design a technology curriculum as part of a coherent teacher education program, technology should be not only integrated with content and pedagogy, but also be considered in relationship to contexts, both internal to the program (for example, in situated practice) as well as how technology is situated in broader contexts, such as the availability of technological tools in K-12 schools, characteristics of today's learners, educational policy, and the impacts of technology on learning and society.

Because it is important to integrate technology with pedagogy, content, and context, developing a coherent curriculum for technology in teacher preparation requires careful attention to various parts of the curriculum. Darling-Hammond et al. (2005) identified three primary elements of a coherent teacher preparation curriculum: content, process, and context. For clarity, in this article we refer to Darling-Hammond et al.'s (2005) construct of context as *situated practice* (see The New London Group, 1996), reserving *context* for the characteristics, resources, tools, and policies of the teacher preparation program and surrounding community. Next, we briefly define these elements as related to technology integration. Additional detail on these elements are provided later in the article. Figure 1 provides a graphic organizer of these key elements.

Figure 1
Designing a Coherent Curriculum for Teaching With Technology



The first element of a coherent teacher preparation program is the content of the curriculum: What do teacher candidates need to know and be able to do by the time they graduate? Several organizations have outlined technology standards and competencies for teacher candidates, and the teacher education technology curriculum should carefully align to these standards. Whether the standards are content specific or general teacher preparation standards, uses of technology should be integrated across the program.

The second element of a coherent program is process: When and how are teacher candidates going to be introduced to and practice the content? What role might a technology course or courses play in candidates learning how to teach content with technology? What types of technology experiences beyond technology courses might be effective? For instance, candidates can engage with technology-rich learning experiences within courses focused specifically on technology, as part of content or methods courses, and as part of clinical experiences. Curriculum designers should carefully plan technology *touchpoints,* or opportunities for candidates to learn about and practice technology in teaching, across the teacher preparation program, considering a developmentally appropriate sequence of activities that address a rich curricular coherence across the program.

Central to the curricular process is situated practice (The New London Group, 1996; see also Lave & Wenger, 1991), the third element of a coherent program. Learning, including developing competency in using technology in teaching and learning, is situated in content areas as well as professional communities and classrooms, and candidates need experience utilizing technologies in their developing practice. Situated practice should include modeling, practice, and feedback or reflection (Hagger & McIntyer, 2006; see also Jin et al., 2023; Skinner, 2010). In other words, effectively using technology in teaching should not only be taught but also become a part of candidates' practice. This suggests effective technology use should be modeled and practiced throughout the curriculum, including during clinical experiences as candidates observe and practice in supported environments.

In this article, we also emphasize context, not only contextual knowledge as discussed previously, but context in relationship to the curriculum itself. For example, what type of teacher preparation program is the curriculum meant to serve? What are the characteristics, resources, and tools of the local schools and community? What resources, including faculty and instructors, are available to draw on? A technology curriculum in teacher education affects a range of stakeholders, including those who teach the courses (faculty and graduate students), teacher candidates, cooperating teachers, and PK–12 schools. Thus, creating technology curriculum that is appropriate in a context requires careful coordination across stakeholders.

The purpose of this article is to discuss curriculum and the curriculum development process, specifically as it relates to the development of a coherent technology curriculum for teacher preparation programs. We start by discussing the curriculum design process, including the challenges of developing a technology curriculum for teacher preparation programs, qualities of successful preparation programs, and considerations for the process of curriculum development. Diverse stakeholders should be involved in the development of the curriculum, and the curriculum design process must be ongoing and responsive to the context, including the dynamics of the program and community context. Next, we discuss content; we provide a brief overview of competencies and standards relevant to teacher education and technology and consider the role of values and context in curriculum design.

We also discuss potential elements of a technology-rich teacher education curriculum, which we label as technology touchpoints. Potential touchpoints might include foundational educational technology courses, subject-specific courses, and tool-specific courses, as well as clinical experiences. Well-planned technology touchpoints can provide opportunities for candidates to participate in situated practice with technology. We discuss the opportunities and challenges of a technology infusion approach, reemphasizing the importance of continuous collaborative curriculum design. Finally, we offer an example of a curriculum for the development of contextualized TPACK across technology touchpoints.

Curriculum Design as a Continuous Collaborative Process

Successfully integrating technology into teacher preparation programs has distinct challenges. First, technology in teaching and learning is situated in subject content areas. For example, utilizing technologies in mathematics requires different knowledge compared to utilizing technologies in science or literacy. This means that rather than technology being its own content, the skills and practices of technology in teacher education need to be part of all other content areas. The TPACK framework proposes that this “interweaving of many kinds of specialized knowledge” (Koehler & Mishra, 2009, p. 61) can be complex, and developing TPACK requires an integrated approach.

A second challenge of technology in the teacher education curriculum is the rapid pace of technological change (Buss et al., 2017; Ottenbreit-Leftwich et al., 2010). The technological tools and applications change over time, and teacher educators must stay up to date on these shifts and how new technologies might support their content. A fluid curriculum is required that is responsive to change as well as ongoing evaluation and development (Simon, 2013).

These two factors — the need to integrate technology into other content areas and the importance of a responsive curriculum — mean that developing a technology curriculum can be uniquely challenging. The curriculum affects many stakeholders, including undergraduate and graduate students, teacher educators, cooperating teachers and schools, technology administrators, and more (Briggs, 2007; Clausen, 2022; Dalrymple et al., 2017; Heard, 2014).

Approaches to curriculum design and adaptation can vary. In some cases, groups of stakeholders follow a step-by-step process. For example, Brewer et al. (2006) outlined a process of collecting the needs of the curriculum from various stakeholders, evaluating the needs of the institution and how well an initial curriculum aligns to those needs, identifying how the curriculum will be implemented, and then implementing the curriculum. Upon implementation, the cycle returns to the beginning (i.e., the collect phase) as a way to engage in a continuous improvement process.

Dalrymple et al. (2017) described a less formalized approach to curriculum design, but one that is long term and contextual. In developing a new science curriculum, they formed two working groups, each with a combination of stakeholders who developed their own ideas for the curriculum. They found such an approach should have meaningful faculty involvement, establish clear leadership for each group, and support communication across working groups.

Similarly, Briggs (2007) conducted a study of 44 high-performing academic departments (individual departments within an institute of higher education) labeled as “continuous planning departments.” These departments gave frequent attention to curriculum and planning, were responsive to various factors that might influence the curriculum, promoted teamwork and participation, and continually evaluated the curriculum (Briggs et al., 2003).

Briggs (2007) noted that, rather than a process or project approach to curriculum, these departments formed a type of community of practice (see Lave & Wenger, 1991) around curriculum development. Effective faculty members learn together, work together to develop instructional materials, and monitor the curriculum. Although individual participation in the curriculum design process may fluctuate, all share ownership of the curriculum. Thus, in these departments, curriculum development is not a one-time event or project; it is an ongoing collaboration.

Common across these curriculum design approaches is the need to include a variety of stakeholders and the emphasis on a continual process. Stakeholders may include faculty members, instructors, graduate and undergraduate students, cooperating teachers and schools, and community members impacted by the change. Each stakeholder brings different concerns and offers different perspectives (Dalrymple et al., 2017; Heard, 2014; Simon, 2013). Therefore, involving them in continual engagement during curriculum refinement processes should be prioritized by program designers.

In all instances, the curriculum design should also be ongoing, whether it is initiated through a formal process or project or developed through informal interactions among stakeholders. In some cases, colleges might begin with a process or project approach to institute major changes, then transition to an ongoing collaborative practice guided by informal interactions. In either case, it is critical that ongoing attention be given to the curriculum in response to changes in technologies, including the technological tools used in schools (Brewer et al., 2006). The curriculum must also be responsive to new discoveries in educational research, change in educational policy, and shifts in societal needs. For example, there is an increasing focus in education research, policy, and practice on the digital competencies and attitudes students need to be successful in an information economy (Kalantzis & Cope, 2010; Voogt et al., 2013).

The next section is a discussion of the types of curricular standards that can form a foundation for teacher preparation program technology curriculum development, as well as the need to look beyond standards and consider the core values and context of the teacher preparation program.

Content, Values, and Context

Central to the curriculum design process is determining what learners need to know — the knowledge, skills, and practices learners need to be successful (Darling-Hammond et al., 2005). The knowledge, skills, and practices are often codified into standards or competencies. In addition to standards, curriculum designers must consider the values behind standards and practices and how these values play out in specific contexts (Simon, 2013).

Published Standards

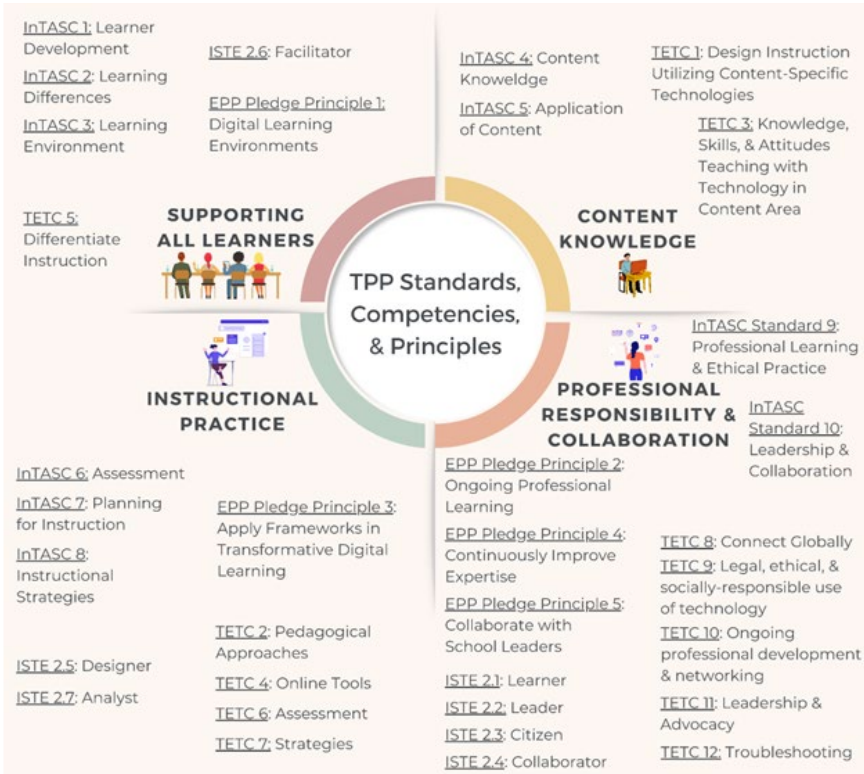
Because a central goal of teacher preparation programs is to prepare graduates to attain licensure, and this licensure requires meeting the criteria set forth by an accrediting body, many programs begin their curriculum with a focus on accreditation criteria. However, the technology criteria set forth by accreditation organizations can be limited and inconsistent (Bullough et al., 2003; Ingvarson et al., 2006). To ensure teacher candidates are technologically self-efficacious after graduation, teacher educators and program designers must look beyond these minimal criteria to more rigorous standards and competencies that target teaching with technology.

Standards of what teachers must know and be able to do come from state education agencies (e.g., *New Mexico State Standards*; New Mexico Public Education Department, n.d.), national organizations (e.g., Interstate Teacher Assessment and Support Consortium **[**InTASC] *Model Core Teaching Standards*; Council of Chief State School Officers, 2013), and international organizations (e.g., IE-UNESCO Global *Framework of Professional Teaching Standards*; Global framework of professional teaching standards, 2022). The target standards can be content-specific (e.g., Association of Mathematics Teacher Educators' [AMTE, 2017] *Standards for Preparing Teachers of Mathematics*), or focus explicitly on the use of technology (e.g., International Society for Technology in Education [ISTE, n.d.] *Standards for Educators***).** Additionally, there are frameworks articulating expectations for teacher preparation programs specific to helping teacher candidates use technology effectively (e.g., U.S. Department of Education, 2017) and equitably **(***Educator Preparation Programs for Digital Equity and Transformation*; ISTE, 2022).

The Teacher Educator Technology Competencies (TETCs) were designed to guide the professional development of teacher educators so they can fully address technology in their teacher education courses (Foulger et al., 2017). An examination of the alignment between standards for teacher candidates (*InTASC Model Core Teaching Standards* and *ISTE Standards for Educators*) with the TETCs and Educator Preparation Programs for Digital Equity and Transformation (EPP Pledge; ISTE, 2022) frameworks reveal common themes. Present across these standards, competencies, and principles are four broad categories (see Figure 2): Supporting All Learners, Content Knowledge, Instructional Practice, and Professional Responsibility and Collaboration.

Standards, competencies, and principles related to the category Supporting All Learners address the ways in which candidates are prepared to support a variety of learners in their classroom. Educators (teachers, teacher educators, and candidates) are able to use technology to facilitate equitable learning opportunities with an understanding of learner development, learning differences, and learning environment. Candidates have Content Knowledge and can design instruction with content-specific technology (i.e., TPACK). The Instructional Practice items in Figure 2 refer to planning and assessment. Educators are able to use appropriate strategies and technologies in instruction.

Figure 2
Teacher Preparation Program Standards, Competencies, and Principles Crosswalk



Note. The Digital Equity and Transformation framework uses the term Educator Preparation Program (EPP) for teacher preparation programs. Other acronyms are InTASC (Interstate Teacher Assessment and Support Consortium), TETC (Teacher Educator Technology Competencies), and ISTE (International Society for Technology in Education).

The largest category in Figure 2 is Professional Responsibility and Collaboration. Educators have a responsibility to engage in ongoing professional development and networking activities to improve the integration of technology in teaching while considering equity and ethics. In addition, they create experiences for their own learners to make socially responsible contributions online that build relationships and community (Council of Chief State School Officers, 2013; Foulger et al., 2017; ISTE, 2022).

Curriculum Values

While Figure 2 provides a visual presentation of frameworks that can guide curriculum design, a focus on standards alone is not enough. Teacher preparation programs must also interrogate and identify core values that will be promoted and sustained through the curriculum as well as the contextual factors and needs of the program. For example, a core value of a program might be creating educational leaders for diverse learning communities, in which case threads of leadership and supporting diverse learners would be woven throughout program experiences. Programs not only embed specific knowledge and skills, but also attitudes, values, and ethics that justify what occurs in a program (Binkley et al., 2012; Erstad & Voogt, 2018). While some of these values might be clear, others might be less articulated yet perpetuate systemic inequities in teacher preparation programs (Simon, 2013).

Leaders of curriculum development must be intentional about revealing existing values and identifying desired values to form the foundation of the future curriculum. For example, Simon (2013) described a process of collecting data through interviews and surveys of a wide range of stakeholders. The designers conducted various analyses of this data including narrative analysis, discourse analysis, and thematic coding to develop a "social construction of reality" (Berger & Luckman, 1966). After building an understanding of the current reality, including inconsistencies in existing and desired values, curriculum designers identified core values (transformative and informed practice, social justice and inclusion, a future orientation, and community capacity building) that would become a foundation for future program design.

Curriculum Context

In addition to technology standards and core values, teacher preparation programs need to ensure that the content of the curriculum responds to the contextual needs of teacher candidates when they enter the field as certified teachers who serve real schools and society. As previously discussed, the curriculum must support teacher candidates in developing and integrating contextual knowledge with content, pedagogical, and technological knowledge (see Mishra, 2019).

Considering context in curriculum design might also include investigating systemic inequities (Porras-Hernandez & Salinas-Amescua, 2013), responding to the cultural values of candidates and the local community (Porras-Hernandez & Salinas-Amescua, 2013), and evaluating new technological tools for their effectiveness to support teaching and learning (Angeli & Valanides, 2005). A systematic curriculum design process can respond to context through establishing an ongoing process that engages a variety of stakeholders who are knowledgeable about contextual elements.

A collaborative interrogation of values and context not only improves technology curriculum development, but it can support the development of a stronger teacher preparation program overall. As previously discussed, big ideas and a shared vision are hallmarks of high-quality and coherent preparation programs (Darling-Hammond et al., 2005; Tatto, 1996), and an investigation of values and consideration of context can improve both vision and coherence.

Touchpoints for Technology Experiences

In addition to content, process should be considered when designing curriculum for teacher preparation programs (Darling-Hammond et al., 2005). Process considers when and how teacher preparation programs integrate the technology into the curriculum. For example, educational technology use might be practiced in foundational educational technology courses, subject-specific courses, tool-focused courses, and clinical experiences (Mouza, 2016; Niess, 2005). Each of these elements could be considered a touchpoint for technology in the teacher education curriculum. This section discusses current literature on ways technology is embedded through these touchpoints.

Not all programs will include the same touchpoints; selecting when technology will be introduced and practiced will vary based on the vision of the preparation program. Timing and sequencing of courses is important. Curriculum developers should consider whether the sequence ensures candidates have the necessary knowledge of content, pedagogy, technology, and context to integrate it into their practice (Gillingham & Topper, 1999). However, preparation programs should also consider what is feasible and most appropriate for their own organizational and situational context (Mishra, 2019). Here, we present these touchpoints simply as possible ingredients that could be part of a cohesive teacher preparation program.

Technology Courses

In a synthesis of research on the preparation of teacher candidates' use of technology, Mouza (2016) identified three pathways commonly utilized by teacher preparation programs, including stand-alone educational technology courses, instructional strategies embedded within content-specific methods courses, and instructional strategies implemented in the context of entire teacher preparation programs. According to this synthesis, the delivery of a stand-alone educational technology course was the most popular pathway, implemented since the 1990s. Existing research revealed several benefits associated with an educational technology course, particularly for improving teacher candidates' self-efficacy and building technological knowledge (TK; Kay, 2006; Mouza et al., 2017).

Yet, research also indicates that without clear connections with content knowledge (CK) and pedagogical knowledge (PK), such courses may not lead to the effective integration of technology into content or discipline area coursework (Foulger et al., 2014). This section describes approaches to the design and implementation of educational technology courses, including foundational educational technology courses, subject-specific courses, and tool-specific courses. We also discuss outcomes associated with each type of course.

Foundational Educational Technology Courses

Foundational educational technology courses are prevalent in teacher preparation programs. These courses typically focus on helping teacher candidates learn about different technologies and how they can be used in teaching and learning (Chai et al., 2013). While initially the focus of these courses was primarily on technology, over time teacher educators focused on reconsidering the curriculum to make it more meaningful and to support teacher candidates as they make connections between technology, content, and pedagogy (Mouza, 2016). More recently, teacher educators have also reconsidered the delivery of foundational educational technology courses, dividing the content into manageable chunks and incorporating it into a series of microcredentials completed by participants during an extended timeframe (Clausen, 2022).

To date, significant outcomes have been reported that explain what the foundational educational technology course can do to prepare teacher candidates to integrate technology in teaching and learning. Findings indicated such a course can prepare teacher candidates to become more confident in using technology and expose them to many technological tools used in classrooms (Foulger et al., 2014). Other findings suggest that teacher candidates' attitudes toward technology will strongly impact their future use of technology (Holland & Piper, 2016; Scherer et al., 2018).

The most effective foundational educational technology courses, however, align theory and practice rather than simply focusing on specific software, providing opportunities for instructional design (e.g., lesson plans and projects), collaborating with peers, reflecting, and connecting to field placements where teacher candidates apply what they learn in practice (Mouza et al., 2017; Tondeur et al., 2012). Courses like these are typically designed by applying the TPACK framework (Mishra & Koehler, 2006) to help teacher candidates learn about new technologies while highlighting specific content and pedagogical strategies (e.g., project-based learning).

In studies where teacher candidates' TPACK is measured in an educational technology course, there are often statistically significant increases shown in participants' knowledge of both pedagogy and technology as well as their overall TPACK (Foulger et al, 2014; Mouza et al., 2017). Koh et al. (2010), for instance, documented significant gains in participants' TPACK before and after their participation in an educational technology course. Similarly, Koh and Divaharan (2011) found significant improvements in participants' TK as well as knowledge in relation to pedagogy and technology. Nonetheless, they found that defined connections between technology and pedagogy with content knowledge (CK) are typically missing from such courses.

As such, Koh and Divaharan (2011) recommended greater emphasis placed on using technology while learning about subject-specific content and pedagogical approaches. For instance, Mouza et al. (2014) reported an integrated approach to the preparation of teacher candidates on the use of technology that juxtaposed an educational technology course with subject-specific methods courses and clinical experience. Findings indicated that participation in the course was associated with gains in teacher candidates' knowledge of content, pedagogy, and technology. Further, candidates could apply their knowledge in practice, though there was variability in the types of knowledge represented in their course assignments.

Subject-Specific Courses

Although foundational educational technology courses remain popular, another strand of research focuses on helping teacher candidates acquire

TPACK while enrolled in subject-specific or content methods courses. This approach helps highlight the connections among content and pedagogy first rather than placing technology at the forefront. The idea is that teacher candidates develop pedagogical and content knowledge at the same time they are learning about and developing their technological knowledge (Segal & Heath, 2020).

Niess (2005), for instance, conducted some of the early studies in the field examining specifically the integration of technology with mathematics and science content in the context of a multidimensional teacher preparation program, which included multiple opportunities to engage with technology in foundation courses, methods courses, and student teaching. Findings from her work indicated that all participants made varying degrees of progress toward the development of TPACK.

Similarly, Özgün-Koca et al. (2010) examined how mathematics teacher candidates developed their understanding of TPACK during a methods course that focused on the implementation of technology-rich activities. Findings indicated that participants improved their understanding of technology in mathematics, although their learning trajectories were influenced by their beliefs about the role of technology in helping students develop mathematical concepts.

Other subject-specific courses have focused on distinct technology tools, such as spreadsheets or GeoGebra in mathematics (e.g., Hahkioniemi & Leppaaho, 2012; Niess, 2007), robotics in science and mathematics (e.g., Suters et al., 2021), mobile technologies in literacy (e.g., Husbye & Elsener, 2013), interactive whiteboards (e.g., Koh & Divaharan, 2011), and geospatial technologies for social studies (Jo, 2016). Overall, such studies demonstrate positive outcomes in relation to teacher candidates' TPACK.

Tool-Specific Courses

Several teacher education programs have started offering tool-specific courses focused on technologies (e.g., makerspaces and robotics). These courses focus on emerging tools that are unique to the topic identified for the course. For example, Cohen (2017) surveyed accredited U.S. teacher education programs and reported that half were integrating *making* into their preparation programs in some manner. Making refers to the use of digital tools in the production and sharing of personalized artifacts.

Some programs reported offering specific courses on making and makerspaces, sites designed to facilitate development of artifacts (Sheridan et al., 2014). For example, a maker-in-residence program (MiR) was specifically designed to support teacher candidates as they learned to integrate makerspace tools and technologies into their future classroom (Heredia & Fisher, 2022).

Results from these studies indicated that participants in making courses benefited by gaining empathy due to the collaboration, problem-solving, and design aspects of the curriculum (Cohen et al., 2017). Specifically, teacher candidates appeared to embrace the opportunity to engage in collaborative learning as well as the cognitive elaboration nature of maker activities and the supportive community that is built around them in such a space. Similarly, courses focusing on robotics for preservice teachers indicated positive outcomes for participants, including enhanced interest in robotics, increased self-efficacy to teach with robotics, and increased understandings of the content associated with robotics activities (Jaipal-Jamani & Angeli, 2017).

Clinical Experiences

Another area for technology touchpoints is clinical experiences such as practicums and residencies, which help situate teacher learning directly into practice. Developing a coherent teacher education curriculum requires not only attention to content (what will be taught) and process (when and how it will be taught), but also where teacher candidates practice and integrate their skills (Darling-Hammond et al., 2005). Research shows that best practices for teacher candidates to experience technology integration in teacher preparation programs include authentic experiences in real PK-12 classrooms (Gillingham & Topper, 1999; Ottenbreit-Leftwich et al., 2010).

For teacher candidates to effectively utilize technology in practice, it must be integrated into field experiences and coupled with opportunities for feedback and reflection (Mouza & Karchmer-Klein, 2013). Traditionally, teacher preparation programs have struggled to facilitate effective technology use in clinical experiences, resulting in limited opportunities for candidates to integrate technology into their practice (Liu, 2012). Several factors impact whether and how candidates use technology in clinical experiences. Hammond et al. (2011) found that candidates' self-efficacy in using technology and their beliefs about technology and learning impacted their use of technology in field experiences. Dawson and Dana (2007) found that teacher candidates' inquiry — or a systematic, intentional study of their own professional practice (Cochran-Smith & Lytle, 1993; Dana & Silva, 2000; Hubbard & Power, 1993) — was a key factor that influenced teacher candidates to change their beliefs about teaching with technology.

To support teacher candidates' technology use in their future classrooms, the development of teacher self-efficacy in technology integration should occur continuously throughout the preparation program experiences, including classroom assignments, modeling by teacher educators and mentor teachers, lesson planning, and field experiences (Williams et al., 2023).

Changing beliefs about teaching with technology, however, may not be enough to facilitate effective technology use in clinical experiences. Additional barriers, such as limited access to technology and Internet in partner schools, as well as support and mentoring available from cooperating teachers, have been found to have a substantial impact on technology use in clinical activities (Dexter & Riedel, 2003; Hammond et al., 2011; Liu, 2012). Choy et al. (2009) identified various challenges to supporting teacher candidates' efforts to utilize technology in field experience, including lack of technology resources, lack of familiarity with student teaching classroom and school setting, increased classroom management duties, and need to address the diverse learning backgrounds of students. These expectations overwhelmed teacher candidates and dissuaded them from teaching with technology, even though they believed that integrating technology would improve student learning.

Developing a Technology-Infused Program

The previous sections highlighted elements for a cohesive teacher education curriculum (content, process, and situated practice) and discussed the unique challenges of technology within such a curriculum. Specifically, technology-rich experiences need to be embedded in content areas, and the rapidly changing pace of technologies requires ongoing adaptation. This section describes the dynamics of a technology infusion approach in the teacher preparation curriculum. Notably, many key elements of the continuous collaborative curriculum design, such as participation of diverse stakeholders and ongoing engagement in curricular revisions, are also critical to developing and sustaining a technology-infused teacher preparation curriculum.

One of the four guiding principles in the 2017 *National Education Technology Plan Update* was that teacher preparation programs should "Ensure pre-service teachers' experiences with educational technology are program-deep and program-wide, rather than one-off courses separate from their methods courses" (U.S. DoE, OET, p. 35). Similarly, Foulger et al. (2017) claimed, "The ultimate goal for teacher preparation programs should be a technology infused program that provides a more concerted effort to address teaching with technology throughout the curriculum" (p. 416).

In an infusion approach, technology is woven throughout the curriculum in meaningful ways, which can include the touchpoints described in the previous section: foundational educational technology courses, subject-specific courses, tool-specific courses, and clinical experiences. Designing a technology infused program does not imply that the teacher preparation programs should eliminate their required educational technology courses (Clausen, 2022). As Wilson et al. (2020) pointed out, these courses provide teacher candidates foundational knowledge for technology integration.

Implementing technology curriculum in teacher education requires consistent attention over time (Fullan, 2007; Hall & Hord, 2015) and structural support. Program leadership should emphasize that "technology use is an expected element that should be evident throughout the [teacher preparation program]" (Clausen, 2022, p. 283). Support for teacher educators might be given through advocacy, recognition, and incentives to help them make the use of technology a priority (see also Kolb et al., 2018). Gillingham and Topper (1999) suggested that incentives may increase teacher educators' likelihood of participating in a technology infused program.

A technology-infused program requires digitally competent faculty members who model the use of hands-on experiences with digital technologies within their own teaching practices while bridging the gap between the content taught in programs and PK-12 education (Jin et al., 2023). More specifically, faculty members explain the clear connections to theory, substantiate the underlying pedagogical and educational choices, and explicitly connect aspects of technology, pedagogy, content, and context and the underlying relationships (Koehler et al., 2004; Lunenberg et al., 2014). These faculty members should collaborate with each other, PK-12 classroom teachers, and other stakeholders to stay abreast of the effective uses of digital technology.

Training teacher educators will also help ensure the success of a technology infused program. Teacher educators should participate in professional development about new tools, software, programs, apps, websites, and curriculum (Buss et al., 2017; Clausen, 2020). The type and degree of professional development will vary for each teacher educator based on their prior background with educational technology integration and confidence in using technology. Program administrators should have realistic expectations about how much fidelity can be expected in the adoption of a newly developed curriculum, especially when some instructors may have little experience with teaching with technology and when instructors have various areas of content expertise (Foulger et al., 2019).

Extensive professional development will be needed to support such instructors, and these opportunities will need to be both general and content specific. Thus, professional development must be supported by technology integration specialists whose responsibility would be to provide training and ongoing support (e.g., Buss et al., 2017). Face-to-face or online workshops, one-on-one peer mentoring, graduate student mentorship, just-in-time training, in-class modeling, coteaching, and ongoing dialogue among those teaching in the teacher education program should all be considered to address building capacity in the teacher education faculty (Foulger, 2020).

Along with professional development, Collier et al. (2004) found that faculty teacher educators who visited elementary classrooms several days per week were aware of technologies available for classroom instruction along with the types of tasks in-service teachers were expected to accomplish with technology. As a result, teacher candidates increased their proficiency with and use of technology. Professional development is imperative so that faculty members and instructors are digitally competent role models. Research shows that a critical factor influencing new teachers' adoption of technology is the quality and quantity of teacher candidates' technology experiences in their teacher preparation programs (Agyei & Voogt, 2011; Drent & Meelissen, 2008).

Planning for a Coherent Technology Education Curriculum

This article has discussed curriculum design specifically as it applies to technology in teacher preparation. A coherent curriculum requires that programs are founded on core principles and practices and that these principles and practices are evident throughout the program (Darling-Hammond et al., 2005). Developing any curriculum to meet this standard can be challenging, but a technology curriculum for teacher preparation has unique challenges: Technology must be integrated across subject areas, and the practices and tools of technology are constantly evolving. This circumstance calls for a deliberate approach to curriculum and curriculum design, one that emphasizes coherence and adaptation.

Building on the work of Darling-Hammond et al. (2005), we have discussed elements of a teacher preparation curriculum: content, process, situated practice, and context. We introduced the term touchpoints to describe opportunities for learning about and practicing teaching with technology. Curriculum designers should carefully consider the most appropriate touchpoints for their context, and to support a coherent curriculum, these touchpoints should provide opportunities to integrate various types of knowledge, including content-related, pedagogical, technological, and contextual knowledge.

Table 1 provides an example of how curriculum designers might evaluate possible technology touchpoints across the curriculum. On the left are possibilities for technology touchpoints, including various types of courses, informal learning activities, and clinical experiences. Each touchpoint is then evaluated for what type of knowledge integration it will best support. The TPACK framework, including the construct of technological contextual knowledge (TXK; see Mishra, 2019), guides the analysis.

Technology Touchpoints	**TK**	**TCK**	**TPK**	**TXK**	**TPACK**
Technology Literacy Course	X			X	
Foundational Educational Technology Course	X		X	X	
Subject-Specific Technology Course		X			
Tool-Specific Course (makerspace)	X	X	X		
Methods Courses (general)		X	X		X
Pedagogy and Theory Course			X		
Informal Learning Opportunities (service learning)	X			X	
Clinical Experiences				X	X

For example, the curricular program in Table 1 includes a technology literacy course that focuses on foundational practices with technology (TK) as well as the role of technology in society (TXK). A course on pedagogy and learning theory could incorporate technology as it supports pedagogy (TPK), as well as the relationship between learning theory and technology (TXK). The types of integrated knowledge of each touchpoint may vary across programs; Table 1 is just one example. This type of analysis of the role of various technology touchpoints in the curriculum supports the unified vision and careful sequencing characteristic of coherent teacher preparation programs.

Conclusion

A technology infusion approach complements the idea of designing a coherent curriculum for teaching with technology; rather than technology practices being separate from the curriculum, technology practices become part of the content, process, and situated practices of teacher educators and candidates across the program. Designing and implementing such a program requires collaboration amongst stakeholders, including partner teachers and schools. Furthermore, curriculum development cannot be a single event; the curriculum must be constantly evaluated based on candidate outcomes, and curriculum designers must adapt to new changes. Thus, a continual collaborative process for curriculum design is critical to support the development of a strong technology-infused curriculum in teacher preparation programs.

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