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Design Principles for Modeled Experiences in Technology-Infused Teacher Preparation

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Modeling is a widely adopted and frequently used strategy to prepare teacher candidates for technology integration. However, whether modeling as a strategy alone is enough for technology-infused teacher preparation programs is questionable. Therefore, the purpose of this paper is to describe an investigation of how teacher educators model technology use in various settings. Our research utilized an integrative literature review methodology to establish search and inclusion criteria. The authors initially screened 674 papers published between 2012 to 2022. A secondary review included 65 articles for full-text analysis. Results show that ample empirical evidence demonstrates the positive impacts of modeling while simultaneously emphasizing that modeling alone is not enough. Furthermore, there are quantitative and qualitative disparities in the modeling practices of faculty and cooperating teachers. Overall, the literature review underscores the need for a more intentional approach to designing learning experiences that model technology integration. The authors summarize a review of literature as research-based design principles, implementation strategies, and competencies teacher educators need to be excellent at modeling. The design suggestions will be helpful for program designers, teacher educators, and those supporting field experiences who wish to contribute to building technology-infused teacher preparation programs.

This article is one of four articles in an invited special issue coedited 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.

The construct of technology infusion draws on a principle from the 2016 U.S. Department of Education/Office of Educational Technology (U.S. DOE/OET) policy brief that called for educator preparation programs to "ensure preservice teachers' experiences with educational technology are program-deep and program-wide, rather than a one-off course separate from their methods courses" (p. 9). Technology integration is where educators or learners use technology during the teaching and learning process (i.e., utilizing digital graphic organizers to create mind maps of the water cycle; Borthwick et al., 2020). Technology infusion, on the other hand, encompasses the entirety of a candidate's preparation to become a teacher. Foulger (2020) defined technology infusion as "a program-deep and program-wide approach within a teacher preparation program to help teacher candidates learn how to leverage technology in their future teaching (i.e., in PK-12 classrooms)" (p. 6).

Building capacity for technology infusion requires preparation programs to consider the many organizational factors involved, including the design of coursework and the instructional practices of faculty (Clausen, 2020). A technology-infused teacher preparation program (TPP) embeds learning to teach with technology throughout all aspects of a teacher candidate's experiences.

Foulger (2020) defined four pillars that support preparation programs: (a) developing an integrated curriculum that spans certification programs (Sprague et al., this issue); (b) providing models of practice during candidate participation in university coursework, methods courses, practicum, and student teaching experiences (Jin et al., this issue); (c) creating opportunities for candidates to practice with and reflect on technology use for learning and teaching (Warr et al., 2023); and (d) designing experiences that provide continual and intentional growth technology self-efficacy (Williams et al., this issue). Those who support teacher candidates, including university faculty and PK-12 cooperating teachers, are key stakeholders throughout the process of learning to teach with technology.

This approach addresses the need to use technology throughout a candidate's preparation program experience and ties to the calling from the 2016 *National Educational Technology Plan* to "develop a common set of technology competencies for university professors" (p. 37) and the U.S. DOE/OET (2016) policy brief to "build sustainable, program-wide systems of professional learning for higher education instructors to strengthen and continually refresh their capacity to use technology tools to enable transformative learning and teaching" (p. 9).

Teacher educators' modeling of technology use has been suggested as a key element in preparing candidates to use technology (Tondeur et al., 2012; Trainin et al., 2018). In 2022, the U.S. DOE/OET and the International Society for Technology in Education (ISTE, 2022). partnered with leading teacher education, educational technology, and accreditation organizations to develop the Educator Preparation Programs (EPP) Digital Equity and Transformation Pledge. The EPP Pledge asks preparation programs to build teacher skills that support the success of PK-12 students in digital environments and to capitalize on a "once in a generation" moment to create lasting change in educator preparation (see Introduction). The EPP pledge includes five principles:

1. Prepare teachers to thrive in digital learning environments.
2. Prepare teachers to use technology to pursue ongoing professional learning.
3. Prepare teachers to apply frameworks to accelerate transformative digital learning.
4. Equip all faculty to continuously improve expertise in technology for learning.
5. Collaborate with school leaders to identify shared digital teaching competencies. (U.S. DOE/OET, 2022)

In a more detailed explanation of Principle 4, EPPs were called on to support all faculty members being equipped to continuously improve their expertise in technology for learning. Principle 4 especially emphasizes that all faculty members need to model technology integration effectively to help candidates build their competence and confidence. Many preparation programs agree to the ideas presented in the EPP Pledge, as evidenced by over 60 institutions having signed the pledge within the first few months of its release (ISTE, 2022).

With a continued emphasis that teacher educators use models and modeling in their repertoire of teaching techniques, a review of the literature is needed to identify effective modeling practices. Two prior reviews of literature focused on technology integration within teacher preparation (Rokenes & Krumsvik, 2014; Tondeur et al., 2012). With the development of technology infusion approaches to preparing teacher candidates, it is time for a new review that examines modeling strategies and approaches used by teacher educators to prepare candidates to integrate technology within their own instruction.

The purpose of this paper is to support teacher educators in leveraging the power of models and modeling in their teaching. To fulfill this need, we reviewed 674 published articles about the ways university faculty and PK-12 cooperating teachers model technology integration for candidates. The focus of this review is to document teacher educators' modeling of technology integration to candidates in TPPs.

Method

This literature review used the integrative methodology (Russell, 2005; Torraco, 2005) to examine empirical studies and practitioner scholarship with the goal of translating research findings into evidence-based practices

(Toronto & Remington, 2020). Because the concept of technology infusion in teacher preparation is novel, studies published in the last decade were considered relevant for this literature review. Additionally, only articles published in English were considered. Data collection and analysis followed the six-step procedure of integrative review: (a) formulate purpose and/or review question, (b) search and select literature, (c) appraise for quality, (d) analyze and synthesize, (e) discuss and conclude, and (f) disseminate findings (Toronto & Remington, 2020). All five authors were involved in these six processes.

Data Collection

To help formulate parameters around selecting literature, we first consulted with experts in the field of teacher preparation and technology integration. Based on their recommendation, we reviewed selected articles (as recommended in Cooper, 1998). With a better understanding of what literature could provide, we worked together to establish search terms that would align with the purpose of this study: *teacher education, teacher educator, teacher candidate, model(s)/modeling,* and *technology integration*. Three databases, Web of Science (WoS), Education Resources Information Center (ERIC), and Google Scholar, were selected. Google Scholar was selected for its comprehensive coverage of research topics. WoS and ERIC were selected because they are focused databases for education, technology, and social science research. PsychINFO and Scopus databases were excluded because coauthors lacked access and anticipated saturation of articles. After determining the search terms and relevant databases, we used the following Boolean search to identify journal articles and book chapters:

> (("teacher education" or "teacher educator" or "teacher preparation" or “preservice”) and (model or modeling or modelling or models) and (technology or technologies or digital)) and integration.

As a result, 295 articles were identified from Google Scholar, 276 from Web of Science, and 347 from ERIC. Among these 918 articles, 250 articles were duplicates and were deleted, resulting in 668 total articles. We then used the reference lists from key articles as recommended by Conn et al. (2003) to conduct ancestry (searching in the reference lists), grey literature (manually searching), and networking (identifying researchers' related studies) searches. This process resulted in six additional articles. In total, 674 identified studies met our literature search criteria.

Next, all five authors worked together to create clear inclusion and exclusion criteria. Using the initial criteria, the first author conducted an appraisal of 59 articles published in 2022 and refined the inclusion and exclusion criteria. Afterward, the five authors came to a consensus on the inclusion and exclusion criteria through a team discussion (as in Hempel et al., 2016). See Table 1 to review the final inclusion and exclusion criteria.

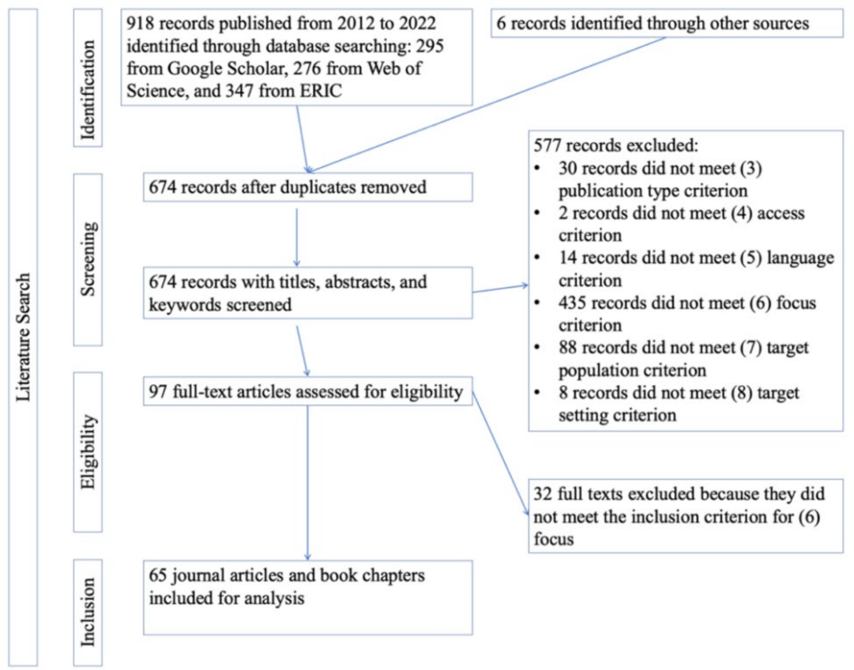
Table 1
Inclusion and Exclusion Criteria

Criteria	Included	Excluded
Databases (1)	Web of Science (WoS), Education Resources Information Center (ERIC), Google Scholar	PsychINFO, Scopus
Time frame (2)	2012–2022	Articles published before 2012 and after 8/20/2022
Publication type (3)	Peer-reviewed journal articles, book chapters, and reports (including both empirical studies and practices papers)	Books, conference proceedings, editorials, dissertations
Access (4)	Full text available for download	No full-text available for the authors to access without payment/subscription
Language (5)	Written in English	Written in other languages
Focus (6)	-Has the term, model/modeling, in the title, abstract, keywords, and/or main text -Focus on teacher education/educator preparation -Focus on learning experiences that model technology integration	-Does not have the term, model/modeling, in the title, abstract, keywords, or main text -Does not focus on teacher education/educator preparation -Focus on other aspects (i.e., statistical modeling, conceptual models)
Target population (7)	Focus on teacher candidates, teacher educators, and cooperating teachers	Focus on PK-12 students, inservice teachers, and/or other populations
Target setting (8)	In teacher education /educator preparation programs	Settings that have no connections to the teacher education/educator preparation programs

For most of the articles, we were able to determine whether to include or exclude the study by reading the article's title, abstract, and keywords. In the rare case where it was difficult to determine the relevancy of a study, the team members held a discussion and reached a consensus. As a result, 577 articles were excluded from the full-text analysis: 30 articles did not meet the publication-type criteria, two articles did not meet the access criteria, 14 articles did not meet the language criteria, 435 articles did not meet the focus criteria, 88 articles did not meet the target population criteria, and eight articles did not meet the target setting criteria.

Next, we shared the responsibility of reading the remaining 95 articles to determine whether to include or exclude each one; 32 articles were excluded. Hence, 65 articles met all inclusion criteria and were included in the final analysis. Figure 1 shows the literature screening and appraisal flowchart. Appendix A, Overview of the Included Articles, provides an overview of the 65 articles.

Figure 1
Literature Screening and Appraisal Flowchart

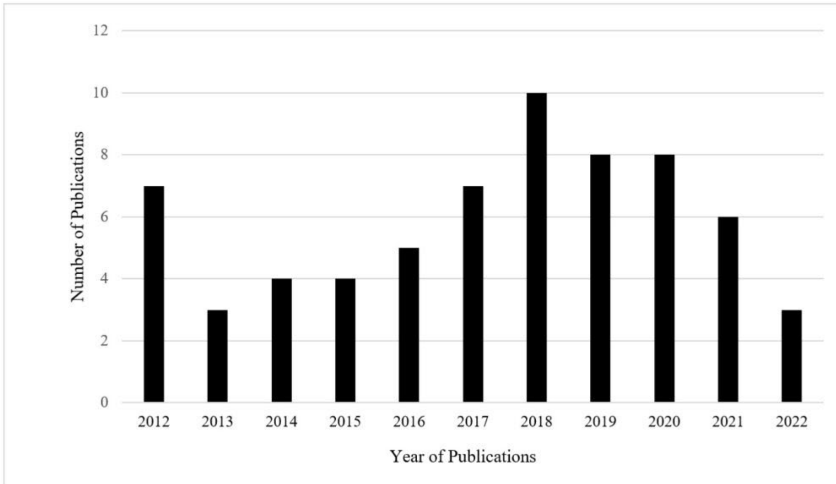


Data Analysis and Synthesis

During the analysis and synthesis phase, the 65 articles were classified using a thematic synthesis process for literature review, with both deductive and inductive thematic analyses (Braun & Clark, 2006). During the initial literature review, the first author conducted open coding on 16 manually selected articles, and then we worked together to finalize the codebook. For each of the 65 included articles, a researcher read the full text and coded the study. Finally, we summarized the findings into common themes, explored the relatedness of the themes, integrated themes into a coherent whole, and refined and refocused those themes (as in Cronin & George, 2020).

Figure 2 illustrates the number of published articles from 2012 to 2022. Among the 65 articles, 17 articles described quantitative studies, 20 articles described qualitative studies, 20 articles described mixed-methods studies, five described literature reviews, and three were reports. The entire set of articles represents work from international authors: United States (30), Turkey (5), Australia (4), Taiwan (3), Netherlands (2), Canada (2), Chile (1), Israel (1), Indonesia (1), Hong Kong (1), New Zealand (1), Norway (1), Sweden (1), and multiple authors from different countries (12). The spread over years, methods, and scholars' nationalities validates the range of published research findings and reports in this literature review.

Figure 2
The Number of Published Articles Included from 2012 to 2022



Results

This section reports the results of this integrative review focusing on empirical evidence on the effectiveness of modeling technology integration, designing learning experiences in TPPs, and the technology competencies teacher educators need.

Empirical Evidence on the Effectiveness of Modeling Technology Integration

Modeling's Benefits to Teacher Candidates

Based on our synthesis of the literature, ample empirical evidence demonstrates the benefits of modeling technology integration to teacher candidates. First, frequent and high-quality modeling from faculty and cooperating teachers helps develop teacher candidates' technological-related knowledge domains, such as technology knowledge (TK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPCK; Baert & Steward, 2014; Cheng et al., 2022; Mishra, 2019; Neumann et al., 2021; Trainin et al., 2018).

Researchers also found that frequent and high-quality modeling positively impacted candidates' teaching and technology self-perceptions, technology, pedagogy, and content knowledge (TPACK), self-efficacy, teaching and design beliefs, and intention to integrate technology (Chai et al., 2019; Han et al., 2017; Menon et al., 2018; Nelson & Hawk, 2020; Neumann et al., 2021; Trainin et al., 2018; Zipke et al., 2019). Modeling significantly improved candidates' technology knowledge and skills and enhanced their sensitivity to the complex interactions between technology, pedagogy, and subject matter (Chang et al., 2012). Modeling also facilitated candidates' critical examination of the affordances of technology for their teaching practices from the perspectives of content selection, motivation to activate students' cognitive efforts to think harder on the content area, information presentation, activity design, and pedagogy transition to more blended teaching using both student-centered and teacher-centered pedagogical approaches (Chien et al., 2012). Furthermore, modeling was suggested to be an important motivator for candidates to use technology in their teaching practices (Admiraal et al., 2017; Donner & Kumar, 2016; Gill et al., 2015; Lu & Lei, 2012; Rownston et al., 2021; Zipke et al., 2019).

In addition, several studies reported a positive association between the strategies used to prepare teacher candidates for technology integration — including modeling — and candidates' perceptions, self-efficacy, information and communications technology (ICT) competencies, and TPACK development (Baert & Steward, 2014; Baran et al., 2019; Sardone, 2019; Scrabis-Fletcher et al., 2016; Semiz & Ince, 2012; Tondeur et al., 2018). According to Cuhadar (2018), candidates rated using teacher educators as role models as the most frequently adopted strategy in TPPs. Candidates also reported that they preferred teacher educators modeling various content-specific and technology-integrated teaching approaches (Semiz & Ince, 2012).

Likewise, Baran et al. (2019) found that reflection and teacher educators as role models were the most frequently used strategies in TPPs. Such studies indicate that when more frequent and effective modeling was used by teacher educators, candidates' TPACK, technology integration self-efficacy, ICT competencies, and instructional technology outcome expectations were more developed, resulting in direct transfer to their teaching practices (Baert & Steward, 2014; Semiz & Ince, 2012).

Although most studies reviewed justified the beneficial effects of modeling, some scholars argued that modeling alone might not be enough to help teacher candidates design their own content-specific and technology-integrated instructions (Charbonneau-Gowdy, 2015; Eutsler, 2022; Hsu & Lin, 2020; Hughes et al., 2016; Tondeur et al., 2016). For example, Hsu and Lin examined six strategies used to prepare teacher candidates for technology integration. They discovered that role modeling, despite its wide adoption and high acclaim, was ranked only third in its positive impacts on candidates' knowledge and attitudes toward technology integration, following reflection and instructional design as the highest.

Candidates also have their own preferences for the strategies used to prepare them for technology integration. Tondeur et al. (2021) surveyed 931 candidates and discovered that candidates experienced their preparation for technology integration differently. Teacher candidates who had more positive attitudes favored collaboration, while those with less positive attitudes needed ongoing feedback. Both studies pointed out candidates' diverse learning needs and profiles and illustrated that modeling alone is insufficient.

Modeling Alone Is Not Enough

Why is modeling the most widely adopted and frequently used strategy, yet not enough to prepare teacher candidates for technology integration? One reason might be that in practice, teacher educators ask candidates to learn and design lessons that are inconsistent with their prior knowledge and experiences in PK-12 classrooms (Eutsler, 2022; Ryu et al., 2019). Moreover, there are apparent differences in the amount and ways faculty members and cooperating teachers model teaching with technology, resulting in candidates having varying impressions of the experiences (Goldstein & Tesler, 2017; Henderson et al., 2013; Hughes et al., 2016; Krause & Lynch, 2018; Martinovic & Zhang, 2012; Nelson & Hawk, 2020; Polly et al., 2020; Ryu et al., 2019; Roulston et al., 2019; Scrabis-Fletcher et al., 2016).

Martinovic and Zhang (2012) highlighted that inadequate and scarce modeling of the pedagogical use of educational technology, both in schools and TPPs, was one of the biggest challenges to overcome. Moreover, Hughes et al. (2016) observed that candidates had divergent experiences of modeling the use of technology by their teacher educators. In other words, some candidates experienced ample and exemplary modeling throughout their TPPs, while others lacked enough high-quality modeling. A major reason is that teacher educators have different expertise and autonomy in technology integration themselves. These differences cause a lack of consistent, systematic, and contemporary coverage of education technology in TPPs, especially technology advancement and innovation.

Tondeur et al. (2019) confirmed the inconsistency in teacher educators' attitudes, self-efficacy, competencies, and the strategies they use for technology integration. Teacher educators involved in their study either scored high or low on all aspects of the survey instrument. When teacher educators rated themselves high on all these variables, they would be more inclined to use strategies for modeling. In parallel, PK-12 cooperating teachers also have varying attitudes toward technology integration, resulting in either ample opportunities for candidates to integrate technology during field placement or discouragement and limited chances for technology integration (Gill et al., 2015).

Polly et al. (2020) found that teacher education faculty members paid special attention to modeling how to integrate technology to teach higher order thinking skills, while cooperating teachers mostly modeled technology integration in lower level activities. Nelson and Hawk (2020) found that field experience has a positive impact on teacher candidates' beliefs and intentions to integrate technology only when they observed frequent technology integration used by skilled cooperating teachers with Meaningful Learning approaches (meaningful learning with technology occurs when the learning is active, constructive, intentional, authentic, and cooperative; Koh et al., 2014). However, such observations were quite rare in the field. Voithofer and Nelson (2021) surveyed 843 teacher educators and found that technology integration showed a relatively low level of TPACK adoption, and most of them experienced disconnects between teaching (e.g., modeling), program coordination, field experiences, policies, accreditation, and their programs' practices. Additionally, Vasinada et al. (2017) argued that technology access alone is not sufficient for teacher educators to model technology integration and design suitable learning experiences for candidates.

Teacher educators need time for exploration, experimentation, practice, and professional learning opportunities, especially for those subject area experts who need to model technology integration in content-specific ways. As a result, due to the contradictory perceptions, inconsistent amount, and quality of modeling received, candidates tend to use technology in didactic ways instead of value-added, student-centered approaches.

The ideal situation for modeling to be used as a method to prepare candidates to teach with technology involves both faculty members and cooperating teachers having a certain level of understanding and experience with technology integration, as well as having a positive attitude about technology integration. More targeted professional learning for teacher educators, including faculty members and cooperating teachers, that is holistic and systematic in addressing all these factors is needed (Tondeur et al., 2019; Uerz et al., 2018).

Strategies for Modeled Experiences

According to the empirical evidence, modeling alone is not enough. Therefore, some scholars proposed a more comprehensive way to prepare teacher candidates for technology integration by intentionally using a variety of strategies (Bell et al., 2013; Brenner & Brill, 2016; Rokenes & Krumsvik, 2014; Tiba & Condy, 2021; Tondeur et al., 2012; Wetzel et al., 2014). Tondeur et al. (2012) conducted a literature review of 19 qualitative studies and summarized seven specific strategies teacher educators should use to prepare candidates for technology integration, including (a) aligning theory to practice, (b) using teacher educators as role models, (c) reflecting on attitudes about the role of technology in education, (d) learning technology by design, (e) collaborating with peers, (f) scaffolding authentic technology experiences, and (g) moving from traditional assessment to continuous feedback. Comparably, Rokenes and Krumsvik (2014) conducted a literature review of 42 studies and reported eight approaches: (a) collaboration, (b) metacognition, (c) blending, (d) modeling, (e) authentic assessment, (f) learning, (g) student active learning, and (h) bridging the gap between theory and practice.

Candidates provided feedback about their preferred strategies in the following studies:

- Content-specific lessons in which technology was modeled in the context of specific instructional approaches, collaborating with peers, and opportunities for feedback and reflection after teaching lessons (Bell et al., 2013)
- Modeling of, reflecting on, and experimenting with technology integration in teacher education programs and effective field experiences (Brenner & Brill, 2016)
- Projects and workshops on technology, resources, and teacher educators and mentor teachers in schools modeling technology use and integration (Tiba & Condy, 2021)

- Expanding the range of tools, especially age-appropriate ones, providing more instructor modeling of technology infusion, and offering more instructional applications of tools and more pedagogical approaches for using tools (Wetzel et al., 2014)

In all, these findings provide a starting point for teacher educators to design learning experiences that model effective technology integration. The following section describes a further examination of the design principles and implementation strategies for this effort.

Designing Learning Experiences That Model Technology Integration

Various Designs of Modeling

Modeling is a practice used frequently in TPPs and is supported by several learning theories, including behaviorism (e.g., Miller & Dollard, 1941; Skinner, 1954) and constructivism (e.g., Bandura, 1986). Furthermore, modeling can be employed in different pedagogical approaches related to supporting the development of a candidate's instructional practice. For example, Lunenberg et al. (2007) outlined four different types of instructor modeling, including "(1) implicit modeling (which seems to have a low impact); (2) explicit modeling; (3) explicit modeling and facilitating the transition into the student teachers' own practice; (4) connecting exemplary behavior to theory" (p. 597).

Based on this categorization, Moore and Bell (2019) further defined the last three modeling types. Type 2 design of explicit modeling is defined as alerting students to attend to the modeling before or immediately after it occurs plus the modeling. Type 3 design of explicit modeling with reflection includes the two components of the Type 2 design, as well as instructor-led reflection with students on "how the method modeled affected them/their learning and how they may apply it in their own future classroom" (p. 329). Last, the Type 4 design of explicit modeling with reflection and connection to theory encompasses all the elements in the Type 3 design, with the addition of the instructor explicitly making connections to theory.

The Lunenberg et al. (2007) framework suggests modeling as a complex teaching technique, yet the relatively comprehensive Type 4 design does not incorporate a hands-on approach for candidates, which is a well-researched design to support instructional technology (Tondeur et al., 2012). Therefore, we propose another design type, Type 5, which could be useful to teacher educators and PK-12 mentor teachers in their work with teacher candidates. Type 5 would be defined by the additional criteria of explicit modeling with reflection, connection to theory, authentic, hands-on activities/projects, and ongoing feedback (see Table 2). In the next section, we unpack the design principles for the Type 5 design.

Table 2
Types of Modeling Design

Lunenberg et al., 2007	Moore & Bell, 2019	Jin et al., 2023
Type 1: Implicit modeling	Type 1: Implicit modeling	Type 1: Implicit modeling
Type 2: Explicit Modeling	Type 2: Explicit Modeling +alerting students to attend to the modeling before or immediately after it occurs	Type 2: Explicit Modeling +alerting students to attend to the modeling before or immediately after it occurs
Type 3: Explicit modeling and facilitate the transitions into student teachers' own practices	Type 3: Explicit modeling with reflection +built onto Type 2 and add instructor-led students' reflection	Type 3: Explicit modeling with reflection +built onto Type 2 and add instructor-led students' reflection
Type 4: Connecting exemplary behavior to theory	Type 4: Explicit modeling with reflection and connection to theory +built onto Type 3 and add explicit connection to theory	Type 4: Explicit modeling with reflection and connection to theory +built onto Type 3 and add explicit connection to theory
		Type 5: Explicit modeling with reflection, connection to theory, hands-on projects, and ongoing feedback +built onto Type 4 and add authentic, hands-on activities/projects and ongoing feedback

Design Principles and Implementation Strategies

The design principles for creating learning experiences that model effective technology integration is organized into four groups: (a) context and content-specific design, (b) personalized, research-based, and equitable design, (c) explicit and sustained modeling design, and (d) authentic and hands-on assessment design. Appendix B shows all 25 implementation strategies and their supporting literature. Appendix C, Implementation Strategies Mentioned in the Included Articles, shows which implementation strategies the included articles discussed. The included studies only talked about a few strategies in their descriptions of their modeling designs.

Context and Content-Specific Design. One explicit way teacher educators model the use of technology for candidates is by designing learning experiences throughout teacher preparation that showcase content-area expertise. This type of modeling motivates candidate TPACK development by offering examples of the practical application of TPACK (Baran et al., 2019), provides authentic examples of content-specific instruction (Bell et al., 2013), and fosters critical reflection (Baran et al., 2019; Bell et al., 2013; Brenner & Brill, 2016; Ryu et al., 2019; Tondeur et al., 2012). Content-area modeling can be powerful due to its practicality, but on its own is insufficient (Baran et al., 2019). When paired with discussion and other forms of collaborative interaction, instructional modeling in the content areas can be a powerful learning experience for candidates (Bell et al., 2013; Cheng et al., 2022; Neumann et al., 2021; Tondeur et al., 2012; Trainin et al., 2018).

Effective modeling of technology-rich learning experiences requires access to technology throughout TPPs – both in preservice coursework and in the field. Therefore, candidates' access to technology while designing classroom learning experiences is a crucial aspect of modeling (Eutsler, 2022; Neuman et al., 2021; Rokenes & Krumsvik, 2014; Zipka et al., 2019). Further, when teacher educators highlight the transferability of technology integration across various contexts, they build a cognitive bridge between clinical experience and candidates' future practice (Lu & Lei, 2012). Although cooperating teachers' technology usage in the classroom provides additional modeling for candidates, their preparation and access to resources vary significantly from classroom to classroom (Tiba & Condy, 2021).

Personalized, Research-Based, and Equitable Design. Another crucial principle for designing learning experiences that model effective technology integration is that of personalized, research-based, and equitable design. Researchers suggest introducing related literature alongside learning experiences (Audin, 2017), providing space for candidate reflection to justify the use of specific technologies (Kale, 2018), tying instruction to research-based theories for instructional planning (Ryu et al., 2019; Sardone, 2019), and assigning empirical studies about the efficacy of technology integration outcomes in the classroom as part of preservice coursework (Sardone, 2019). In addition to emphasizing the importance of the well-known TPACK framework (Baran et al., 2019; Chai et al., 2019; Mishra, 2019; Mishra & Koehler, 2006; Voithofer & Nelson, 2021), researchers have highlighted the importance of aligning other tech-focused frameworks (e.g., SAMR, Puentedura, 2006) *and* pedagogy-focused principles (e.g., *Understanding by Design*, Wiggins & McTighe, 2005) with learning experiences that model effective technology integration.

When teacher educators successfully tie research-based design principles to the personalized and individualized learning needs of candidates, the outcomes are even more effective (Chai et al., 2019; Charbonneau-Gowdy, 2015; Donner & Kumar, 2016; Jones & McLean, 2012; Voithofer & Nelson, 2021). Indeed, when teacher educators are intentional about addressing the personal, individual, and diverse beliefs of candidates as learners, they also model the complexity of integrating technology according to learner needs (Donner & Kumar, 2016; Voithofer & Nelson, 2021).

Explicit and Sustained Modeling Design. Researchers of the included studies advocate for an explicit and consistent modeling design across disciplines throughout TPPs. Teacher educators should explicitly model how various technologies can be utilized to engage students in active learning and knowledge construction (e.g., Brenner & Brill, 2016; Clausen, 2022; Gawrisch et al., 2020) and explain the clear connections to theory (e.g., Dorner & Kumar, 2016; Eutsler, 2022; Hsu & Lin, 2020; Hughes et al., 2016).

Teacher educators should also provide candidates ample time and opportunities to critically review, analyze, discuss, and reflect on content-specific technology integration examples, applications, resources, and curriculum in a social context, while also considering human and technological infrastructures and social support networks (e.g., Kale, 2018; Lu & Lei, 2012). Another critical component is to offer cognitive modeling of teachers' decision-making/pedagogical reasoning about technology integration in the field, which includes explicit modeling of multiple aspects of technology use in teaching and learning, such as access and availability of technologies, preparation of materials, content delivery, activity design, classroom management, and student characteristics (e.g., Henderson et al., 2013; Hsu & Lin, 2020; Trainin et al., 2018; Uerz et al., 2018; Vaughan, 2014). Finally, teacher educators should design collaborative activities for candidates to interact with various stakeholders, such as peers, faculty, and cooperating teachers (e.g., Brenner & Brill, 2016; Neumann et al., 2021).

Authentic Hands-On Assessment Design. Providing candidates with authentic, hands-on experiences is an essential strategy in modeling effective technology use. Several strategies were identified in the literature review as part of this design and focused on creating, reflecting on, and assessing lesson projects that integrate technology. Almost half of the identified articles (31) provided examples of faculty members using hands-on projects as a modeling strategy for technology integration (e.g., Eutsler, 2022; Henderson et al., 2013; Sardone, 2019).

Along with designing technology integration projects, other strategies facilitate candidate learning, such as offering ample opportunities for ongoing discussion, reflection, and feedback (e.g., Tondeur et al., 2019; Trainin et al., 2018). As part of this process, candidates were provided sustained encouragement (e.g., Chien et al., 2012; Tiba & Condy, 2021), time to revise and refine their lessons (e.g., Aydin, 2017; Tiba & Condy, 2021), opportunities to share their projects with others (e.g., Aydin, 2017; Wetzel et al., 2014), and had occasions to celebrate their learning along the way (e.g., Jones & McLean, 2012). Additionally, assignments and field experiences with modeling activities had explicit evaluation criteria included (e.g., Bell et al., 2013; Dorner & Kumar, 2016).

Instructional Design Models

Design principles and implementation strategies establish a foundation for teacher educators to create learning experiences that model effective technology use. However, teacher educators need a roadmap with plausible sequences and suitable combinations of strategies. A few studies proposed instructional design models for this purpose (see Table 3, Chang et al., 2012; Cheng et al., 2022; Chien et al., 2012; Dorner & Kumar, 2016; Gawrisch et al., 2020).

Table 3
Literature Findings About Instructional Design Models

Reference	Instructional Design Models	Processes
Chien et al. (2012) Chang et al. (2012)	MAGDAIRE (see an illustration of the model in Chang et al., 2012, p. 986).	Phase 1: Modeled Analysis (model [cognitive apprenticeship], externalize the performance and design thinking) Phase 2: Guided Development (transfer the learning materials of the chosen subject matter into the technology-integrated format, technology activities, lesson plan design [activities and assessment], solve authentic pedagogical problems) Phase 3: Articulated Implementation (present, share ideas, discuss, implement lessons) Phase 4: Reflected Evaluation (feedback, compare, revise, and refine design)
Gawrisch et al. (2020)	ID model based on TPACK framework and occupational socialization theory	1. building knowledge and learning to value technology (TK) 2. observation and exploration (TCK, TPK) 3. experimentation with mentoring and scaffolding (TPACK) 4. discovery, innovation, and utilization (TPACK)
Cheng et al. (2020)	DECODE	DE - instructor's demonstrations/modeling CO - collaboration of students/students Co - train the use of ICT guided by the TPACK model DE - the design of the course/students Co-design an ICT-integrated instructional model, and students Co-teach the model and receive feedback
Donner & Kumar (2016)	Mentored Innovation Model	Phase 1: teacher candidates identify pedagogical and methodological problems with other stakeholders Phase 2: teacher candidates create a development project plan and a joint research agenda with mentors and peers Phase 3: teacher candidates identify and adapt or further develop existing learning objects, activities, and lesson plans in collaboration with others

All four approaches to modeling utilize many of the design principles and implementation strategies mentioned in the literature to create intricate learning experiences for candidates. However, a question emerged when we thought about these design processes: What competencies do all teacher educators need to create such sophisticated learning experiences that model effective technology integration for candidates?

Technology Competencies for Teacher Educators

Teacher educators can best serve as role models when their pedagogical behavior is congruent with the behavior they want to promote in their candidates (Lindfors et al., 2021; Uerz et al., 2018). Starčič & Lebeničnik (2020) found that teacher educators act in two ways when it comes to technology use: their actual use or as curriculum developers who understand the nature of a digital curriculum. As transmitters of values and attitudes toward technology use, teacher educators facilitate a deeper understanding of the use of the tool when they introduce new technological solutions through modeling. In addition, Starčič & Lebeničnik recommended including collaborative practices in digital environments, flexible learning environments, and social networking practices in modeling experiences. Wollmann and Lange-Schubert (2022) also encouraged modeling the use of digital media, especially in science teaching, to develop candidate-created digital resources such as videos.

In one study (Admiraal et al., 2017), teacher candidates expressed a need for role models from teacher educators who demonstrate how technology could be used effectively in the teaching of subject matter. Additionally, cooperating teachers in PK-12 schools can serve as role models for candidates during their practice teaching, even if their technology use is not particularly sophisticated. Teacher educators appear to play a vital role in discussing where and how technology is used as a sensible enhancement to learning opportunities. This assertion is supported by Uerz et al. (2018), who suggested that teacher educators could share their own reflections on the development of their competencies.

For teacher educators to engage as role models, Uerz et al. (2018) identified four relevant areas of teacher educator competencies, which include technology competencies, competencies for pedagogical and educational technology use, educator beliefs about teaching and learning, and competencies for innovation in professional learning. Starkey (2020) identified three competencies necessary for teaching in technology-infused contexts: general digital competences, digital teaching competences, and professional digital competencies. The author recommended additional research to understand the professional digital competence for initial teacher education.

In a study by Lindfors et al. (2021), teacher educators agreed that professional digital competence was vital for preparing candidates for their future work but did not perceive themselves as digital role models for this area of knowledge. Tondeur et al. (2019) found that not all teacher educators feel ready for the role of preparing and motivating candidates to innovate with educational technologies. Teacher educators also report inconsistencies within the programmatic design and a scarcity of leadership within TPPs (Clausen et al., 2021). To support the professional development needs of teacher educators, Foulger et al. (2017) proposed 12 Teacher Educator Technology Competencies (TETCs), eight of which specifically promote multiple facets of role modeling in TPPs, particularly in pedagogical approaches and instructional strategies.

Discussion

Design More Holistic Learning Experiences That Model Effective Technology Integration

Many of the studies included in this integrative review supported the benefits of modeling technology integration for teacher candidates. Several studies even found a positive association between modeling and candidates' perceptions, self-efficacy, competencies, and TPACK development. However, the strategy "modeling" has been used loosely in most literature without unpacking the detailed pedagogy of the learning experiences that it involves.

Researchers who conducted quantitative studies had difficulty justifying the effectiveness of modeling as a single strategy and how it impacts candidates' ability to design their own content-specific and technology-integrated instruction. Neither did they mention candidates' ability to transfer strategies into their teaching in field placements. Additionally, although some of the 65 included studies explained intricate modeling pedagogies, most of the literature did not. This made it hard to parse out specific design types and truly understand what design principles are needed for teacher educators, including those teaching general education courses and methods courses, mentors, field experience supervisors, and cooperating teachers to create learning experiences for candidates that model effective technology integration.

In contrast, some researchers have argued that modeling as a strategy alone might not be enough to help teacher candidates design their own content-specific and technology-integrated instructions. The included articles strongly support this argument. Almost all studies utilized a Type 4 (explicit modeling with reflection and connection to theory, Moore & Bell, 2019) or a more complicated design. Thus, the results of our review show that the modeling utilized in the included studies was accompanied by other strategies and the outcomes had a compound effect.

This integrative review extends the literature by advancing the concept of modeling (Lunenberg et al., 2007; Moore & Bell, 2019). We propose a fifth type of modeling, stemming from the synthesis of implications from the literature on modeling effective technology integration. This new type of modeling design includes explicit modeling with reflection; connection to theory; authentic, hands-on projects; and ongoing feedback.

To be more specific, we propose that in this design, teacher educators alert candidates to the fact that modeling will begin, they model the use of a particular technology integration strategy, and then reiterate to candidates the modeling that occurred (see Table 3). Teacher educators should also draw candidates' attention to how the modeled practice connects to a specific education theory. Teacher educators should lead candidates to discuss and reflect on the modeled approach and the ways it affects their learning and future teaching practices. Afterward, teacher educators should offer opportunities for candidates to work on authentic, hands-on projects individually or with peers.

During the projects, teacher educators should again present ample time for ongoing discussion, reflection, and feedback. Specifically, teacher educators should include opportunities for candidates to revise, iterate, and refine lessons where technology is integrated and design the reflection to include contemplation of beliefs, experiential knowledge, funds of knowledge (González et al., 2006), attitudes, and self-efficacy. In practice, a few approaches were used to facilitate this type of design, such as flipped classroom (Setiawan et al., 2018; Vaughan, 2014), blended learning (Montgomery et al., 2015), personalized learning (Jones & McLean, 2012), and collaborative inquiry (Henderson et al., 2013).

For future research, we strongly recommend researchers clearly describe modeling so that it is conceptually clear whether the results are because of modeling or an indication of strategies that are employed alongside modeling. No included study was conducted to compare the effectiveness of the different design types. Future research is needed to explore whether Types 4 and 5 are more effective than Types 1, 2, and 3 in preparing candidates for effective technology integration. Another direction is to explore the contextual factors that might affect teacher educators' design types. Types 1, 2, 3, and 4 might be effective and appropriate in certain contexts, in consideration of time, location, access and availability of technology, content-specific needs, and students' and candidates' equity, diversity, developmental capabilities, and funds of knowledge.

The Need to Model Context, Equity, Diversity, and Inclusion in PCK and TPACK

Connecting technology-infused teaching practices and field applications can be challenged by the vast number of differences in school settings within any given TPP. A multiplicity of approaches to curricular design and delivery for teacher candidates (Voithofer & Nelson, 2017) coupled with unequal access to technology integration in field experiences creates a patchwork quilt of experiences for teacher candidates that vary greatly from program to program. TPPs across the country are signing on to the EPP's Digital Equity and Transformation Pledge, which emphasizes the need for future teachers to "use technology to provide equitable learning opportunities" (U.S. DOE/OET, 2022, Principle 1). Indeed, unlike many other tools at our collective disposal in the classroom, technology has the potential to either reproduce and replicate or expose, resist, and even fracture systems of power and oppression toward equity for all students (Subramony, 2017). However, few of the studies analyzed here discuss technology as a tool for equity.

In contrast, Voithofer and Nelson (2021) pointed to ways in which teaching with technology has the potential to concretize dominant narratives and paradigms through a discussion of Dyches and Boyd's (2017) proposed Social Justice PCK model. More recently, Mishra (2019) updated the TPACK framework to include contextual knowledge (XK), which points to the contextual, situational knowledge embedded in teaching and learning experiences that have the potential to create or recreate inequity. Future research on technology infusion in TPPs requires further exploration of social justice, equity, and diversity contexts. Furthermore, teacher educators need to explicitly model context, equity, and diversity in PCK and TPACK when preparing candidates for technology integration.

Teacher Educators as Essential Role Models

Teacher educators have an essential role in modeling pedagogical applications of technologies, creating curricula through which technology is infused, and building capacity for professional digital competencies for candidates. As such, teacher educators shape the context, manner, and complexity of candidates' technology use through modeling and instructional decision-making. The competencies of teacher educators for teaching with technology both enable and limit their capacity as role models, which manifests as a dialectical tension within teacher educators. These competencies perform an important bridging function between the candidates' growing pedagogical knowledge and their understanding of digital tools and technologies for instruction and content acquisition (technology-related knowledge domains, TK, TCK, TPACK). Additional research is needed to better understand the following:

1. The impact of modeling on future teacher practice;
2. How teacher educators describe their own modeling practices and their beliefs on technology infusion or technology integration;
3. Which critical teacher educator digital competencies need to be cultivated for effective modeling;
4. How to define and assess teacher educators' competencies across TPPs, building upon existing definitions of technology integration competencies; and
5. Best practices for ongoing teacher educator professional learning.

In practice, TPPs need to provide targeted professional learning opportunities to develop all teacher educators' competencies, including course instructors, mentors, and cooperating teachers (Menon et al., 2017). Several articles provided ideas on professional learning approaches (Peng, 2020; Scrabis-Fletcher et al., 2016; Semiz & Ince, 2012). For example, Peng used four instructive approaches, which were hAPPy Friday Tools/Apps' 30-Minute Teaching with Tech Tip Video Series, team-based instructional strategies, one-on-one technology assistance, and the showcase conference. These strategies have demonstrated their usefulness in the formation and augmentation of teacher educators' TPACK development and application for supporting candidates' technology integration.

To reiterate, in practice, TPPs should support all stakeholders with the most up-to-date content-specific educational technology use and develop these stakeholders' competencies as role models, especially the cooperating teachers whose modeling was regarded as the most helpful by candidates (Han et al., 2017; Semiz & Ince, 2012).

The Importance of Technology Infusion for Teacher Preparation Programs

The results of our literature review led us to advocate for modeling designs that support candidate development and technology infusion throughout TPPs. Embedding modeled experiences in every component of TPPs is an imperative part of a program-deep and program-wide technology infusion approach (U.S. DOE/OET, 2016).

A successfully designed technology-infused program will require every stakeholder group to effectively account for the many dynamic contextual factors impacting candidates learning of how to integrate technology (Foulger, 2020). All in all, utilizing a technology infusion method asks every teacher education stakeholder to design learning experiences that model effective technology integration in developmentally appropriate ways for candidates. Appendix D can be a guiding tool for this effort. To achieve the goal of technology infusion, colleges and schools of education should continuously support all teacher educators' development in technology integration competencies, provide targeted professional learning opportunities to all teacher educators on how to design learning experiences that model effective and content-specific technology integration, connect teacher candidate preparation with inservice teacher professional development for synergistic impacts, and establish ongoing and mutually beneficial partnerships with PK-12 schools (Sprague et al., this issue; Warr et al., this issue; Williams et al., this issue).

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Appendix A
Overview of the Included Articles

Author(s)	Year	Country	Methods	Sample Size	Research Purposes
Admiraal et al.	2017	Netherlands	Mixed	49 preservice teachers	To examine how technology infusion is implemented and evaluated and how preservice teachers enact technology infusion in class and how this enactment is evaluated by their students
Aydin	2017	Turkey	Report	/	/
Baert & Steward	2014	USA	Quan	220 preservice teachers	To examine the perceptions of physical education teacher candidates on the integration of technology within a large PETE program that does not require preservice teachers to take an undergraduate technology course; rather, technology is embedded within the program.
Baran et al.	2019	Turkey, Belgium	Quan	215 Turkish preservice teachers	To examine preservice teachers' perceptions of the support their teacher education programs provide for developing their TPACK
Bell et al.	2013	USA	Qual	26 preservice teachers	To explore the effectiveness of a teacher preparation program aligned with situated learning theory on preservice science teachers' use of technology during their student teaching experiences
Brenner & Brill	2016	USA	Mixed	24 early career teachers for surveys 6 for interviews	To identify instructional technology integration strategies and practices in preservice teacher education that contributes to the transfer of technology integration knowledge and skills to the instructional practices of early career teachers
Chai et al.	2019	Hong Kong & Singapore	Quan	564 Singapore preservice teachers	To test a new questionnaire, investigate whether the revised STLDM enhance Singapore preservice teachers' TPACK 21CQK efficacies and their design beliefs significantly, and examine can teachers' design beliefs predict their TPACK-21CQL efficacies

Change et al.	2012	Taiwan	Mixed	16 preservice teachers	To investigate whether preservice teachers' TPACK improved with the MAGDAIRE model
Charbonneau -Gowdy	2015	Chile	Qual	23 preservice teachers	1) To determine whether innovative technology-infused (TI) courses would serve to enable the beginning teacher participants to shed their traditional, passive, rather narrow cultural mindset as individuals and learners that are contrary to the identities of effective, 21st-century teachers; and 2) to see whether opportunities to use a variety of innovative technologies for learning would have an influence on the pedagogies these individuals employed in their teaching practices
Cheng et al.	2022	Taiwan	Mixed	60 preservice teachers	To investigate the effectiveness of the "CloudClassRoom" (CCR) and the DEmo-CO-design/teacher-feedback-DEbriefing (DECODE) model on improving preservice teachers' online TPACK
Chien et al.	2012	Taiwan	Mixed	16 preservice teachers	To investigate whether preservice teachers' TPACK improved with the MAGDAIRE model
Clausen	2022	USA	Qual	/	To describe how a teacher education program is addressing the need to engage candidates and faculty on technology integration and adoption through participation in a Breakout EDU game
Cuhadar	2018	Turkey	Quan	832 preservice teachers	To expose the training and experience that preservice teachers acquire in the course of their study at schools of education in regard to the use of information and communication technology (ICT)
Cydis	2015	USA	Mixed	43 preservice teachers	To examine whether preservice teachers integrate technology into their lesson plans after seeing the modeling of pedagogical practices that integrate authentic, performance-based opportunities for technology integration
Dorner & Kumar	2016	Hungary & USA	Quan	116 preservice teachers	To describe the Mentored Innovation Model's implementation with preservice teachers to support them with technology integration in their teaching

Eutsler	2022	USA	Qual	38 preservice teachers	To examine how does an emphasis on the instructor's pedagogy and implementation of the gradual release of responsibility model influence preservice teachers' use of the iPad to design early literacy instruction
Foulger et al.	2017	USA	Qual	43 articles 17 Delphi participant s	To create Teacher Educator Technology Competencies (TETCs)
Gawrisch et al.	2020	USA	Report	/	To propose a conceptual framework for helping preservice physical educators develop TPACK that is grounded in occupational socialization theory
Gill et al.	2015	Australia	Qual	11 preservice teachers	To report on a study in which a group of 11 preservice primary school teachers were interviewed at stages through their program with a focus on their preparedness to use ICTs in their teaching
Goldstein & Tesler	2017	Israel	Quan	1402 preservice teachers	To examine the impact of the Israeli National Program on pre-service teachers' skills in the integration of ICT in teaching and discusses the influential factors of successful implementation of practices in the field.
Han et al.	2017	USA & South Korea	Quan	55 preservice teachers	To examine how technology-centered student teaching experiences differently affect pre-service teachers with different teaching beliefs with regard to self-efficacy and intention to use technology
Henderson et al.	2013	Australia	Report	/	To select stories that reveal the most significant change according to the project goals; To analyze the selected stories using the lens of organizational learning to identify methods which most effectively assist students to build capacity to pedagogically integrate ICTs into their teaching practice;
Hsu & Lin	2020	Hong Kong	Quan	63 preservice teachers	To examine how the SQD strategies of a 4-week training module affect preservice teachers' perceived technology knowledge and attitudes toward technology adoption
Hughes et al.	2016	USA	Mixed	932 preservice teachers	To examine the nature and change in faculty technological modeling over 7 years

Jones & McLean	2012	Australia	Qual	52 students	To describe one approach to creating a technology-infused learning environment that has been trialed in the tertiary section
Kale	2018	USA	Mixed	82 preservice teachers	To examine the influence of observation of technology demonstrations and review of relevant text resources on the utility value of mobile and social networking tools that preservice teachers recognize in their reflections
Karaoglan Yilmaz & Durak	2018	Turkey	Qual	49 preservice teachers	To investigate pre-service teachers' opinions about how they utilized the steps of Gagne's model while designing digital stories for math lessons
Krause & Lynch	2018	USA	Qual	13 faculty 32 students	To investigate TPACK-related experiences of 13 faculty and 32 students among three PETE programs through a multiple case study design
Lindfors et al.	2021	Sweden	Qual	13 teacher educators	To explore how Swedish teacher educators view individual, collegial, and organizational conditions framing the fulfillment of their dual didactical task, which is to use digital technology in a way that ensures student teachers graduate from teacher education (TE) with the professional digital competence (PDC) needed for their future working lives in a digitalized school
Lu & Lei	2012	USA	Qual	39 preservice teachers	To investigate whether Live Dual Modeling was effective in helping preservice teachers develop TPACK in a technology integration course.
Martinovic & Zhang	2012	Canada	Mixed	64 preservice teachers for the online survey 12 for focus group interviews	To examine preservice teachers' expectations of and attitudes toward the learning and integrating of ICT into their teaching, and their perceptions of the availability and use of ICT in the Teacher Education Programs and their placement school
Menon et al.	2018	USA	Mixed	34 preservice	To investigate changes in preservice elementary teachers' technology self-efficacy during their participation in a specialized

				elementary teachers	science content course that utilized a mobile technology-based physics curriculum, Exploring Physics
Montgomery et al.	2015	Canada	Mixed	3 teacher educators	To explore the digital challenges of student engagement in higher education within the experimental platform of blended learning
Moore & Bell	2019	USA	LR	26 manuscripts	To investigate to what extent does existing literature support instructor modeling as an effective, research-based strategy
Nelson & Hawk	2020	USA	Quan	146 preservice teachers	To investigate how field experiences impact the technology integration beliefs and intentions of prospective preservice teachers
Neumann et al.	2021	USA	Mixed	33 preservice teachers	To investigate using the pedagogies of practice to design a course that prepares preservice teachers to teach with technology in technology-rich and blended environments
Novak & Wisdom	2018	USA	Mixed	42 preservice elementary teachers	To explore how collaborative 3D printing inquiry-based learning experiences affected preservice teachers' science teaching self-efficacy beliefs, anxiety toward teaching science, interest in science, perceived competence in K-3 technology and engineering science standards, and science content knowledge
Ozudogru & Cakir	2020	Turkey	Quan	1040 senior preservice teachers	To investigate preservice teachers' taking teacher educators as role models in the application of technologies in education
Park & Gentry	2017	USA	Mixed	16 preservice teachers	To report on the development of the Collaborative Multimedia Service-Learning (CMSL) model and present the findings of the implementation of CMSL in a partnership between a preservice teacher training program in a 4-year university and area elementary and middle schools
Peng	2020	USA	Mixed	12 teacher educators	To analyze the Technology Teaching Assistantship (TTA) Program's features and impacts on teacher educators' development of TPACK
Polly et al.	2020	USA	Qual	89 preservice teachers	To examine how modeling from both teacher education faculty and clinical educators influenced elementary education teacher

					candidates' development of technology integration knowledge and use of technology while teaching
Rokenes & Krumsvik	2014	Norway	LR	42 empirical studies from 2000 to 2013	To showcase and establish knowledge about empirical research on ICT-training in teacher education and contribute with an overview of approaches for researchers, teacher educators, and policy makers on how teacher education develop student teachers' digital competence for the secondary school grade level
Roulston et al.	2019	UK & Ireland	Mixed	37 teacher educators 8 teacher education providers	To report on teacher educators’ use of digital technologies across the island of Ireland
Rownston et al.	2021	Australia	Qual	17 post-graduate preservice teachers	To understand how career-changers technology pedagogy cognizance developed throughout a post-graduate teacher education program and the determinants that supported or constrained their level of progression
Ryu et al.	2019	USA	Qual	4 preservice teachers, 2 doctoral students	To examine strategies students in the methods course employed in developing integrated STEM lessons, the funds of knowledge they brought to the STEM lesson development, and the challenges experienced
Sardone	2019	USA	Qual	75 preservice teachers	To investigate the level of complexity of the learning experience based on the SAMR model of the technology integrated tasks created by study participants; For participants to consider one way to integrate technology that can result in student engagement
Scrabis-Fletcher et al.	2016	USA	Mixed	91 preservice PETE candidates	To examine preservice PETE candidates' technological and pedagogy skills and their beliefs about and implementation of technology in their classes in an effort to assess which methods of instruction about technology might provide for the greatest learning
Semiz & Ince	2012	Turkey	Quan	760 preservice physical	To identify the TPACK, Technology Integration Self Efficacy, and Instructional Technology Outcome Expectations of preservice physical education teachers; To examine the relationships among

				education teachers	TPACK, TISE, and ITOE; To examine the differences between preservice physical education teachers who perceived and who did not perceive technology integration by their university instructors on TPACK, TISE, and ITOE scores.
Setiawan et al.	2018	Indonesia	Qual	1 teacher educator in English Departme nt	To explore a teacher educator's experiences in modeling his teaching and learning based on the TPACK framework using qualitative research into biographical case study narrative
Starčič, & Lebeničnik	2020	Slovenia & Russia	Quan	1,359 students	To examine student' perception of various technology-based issues: ICT integration within a Slovenian university's learning environment; teachers as role models for ICT use, and the processes of collaboration and creativity as integrative parts featured in learning technologies
Starkey	2020	New Zealand	LR	47 articles	To examine research exploring the preparation of teachers for the digital age through a systematic literature review of articles published between 2008 and 2018
Tiba & Condy	2021	South Africa	Qual	16 preservice teachers	To identify factors influencing preservice teachers' readiness to use technology during student teaching
Tondeur et al.	2012	Belgium, China, & Netherlands	LR	19 articles	To review and synthesize qualitative studies that focused on strategies to prepare preservice teachers for technology integration
Tondeur et al.	2016	Belgium & Norway	Quan	688 preservice teachers	To develop a self-report instrument to measure pre-service teachers' perceptions of the extent to which they experience the necessary support and training in order to integrate technology into classroom activities
Tondeur et al.	2019	Belgium, Norway, USA, Finland	Quan	284 teacher educators in Belgium	To investigate the profiles of teacher educators and explore their ability to prepare preservice teachers for technology integration

Tondeur et al.	2021	Belgium & Australia	Quan	931 preservice teachers in Belgium	To examine 1) the key relationships among strategies to develop preservice teachers’ digital competencies and 2) how the self-organization of these strategies changes in relation to pre-service teachers’ attitudes towards digital technology
Tondeur et al.	2018	Belgium & Australia	Quan	931 final-year preservice teachers in Belgium	To test a model to explain preservice teachers' perceived ICT competencies that integrates their background characteristics, ICT profile, and strategies they experience in teacher education programs.
Trainin et al.	2018	USA	Quan	891 preservice teachers	To examine how the teacher education program impacted preservice teachers' technology integration in the classroom with the redesigned teacher education program
Truesdell & Birch	2013	USA	Mixed	28 preservice teachers	To examine how a teacher education program integrate new instructional technology through the creation of a Technology Facilitator position in the department
Uerz et al.	2018	Netherlands	LR	26 research articles	To present an overview of research literature on teacher educators' competences in preparing their students to teach with technology
Vasinda et al.	2017	USA	Qual	4 teacher educators	To document 4 teacher educators' technology integration journey through collaborative autoethnography identifying the affordances and challenges of 1:1 iPad integration into their science, social studies, and literacy methods courses.
Vaughan	2014	USA	Qual	/	To explore the use of a flipped classroom model to engage preservice teachers in an Introduction to the Teaching Profession course.
Voithofer & Nelson	2021	USA	Mixed	843 teacher educators	To determine how teacher educators are working to prepare new teachers to integrate technology and how teacher educators, and by extension teacher education programs, were implementing the TPACK model.
Wetzel et al.	2014	USA	Qual	5 focus groups of preservice teachers	To examine how well and in what ways were candidates prepared to teach P-12 students to use and integrate technology to meet content standards or pedagogical standards.

Zipke et al.	2019	USA	Mixed	67 preservice teachers	To explore a modeling technique for integrating technology instruction into preservice teachers' coursework

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Appendix B
Design Principles and Implementation Strategies for Creating Modeled Learning Experiences

Design Principle	Implementation Strategies	Citations
Contextual and content-specific	1) Teacher educators have and showcase content area expertise	Baran et al., 2019; Bell et al., 2013; Brenner & Brill, 2016; Cheng et al., 2022; Dorner & Kumar, 2016; Eustler, 2022; Neumann et al., 2021; Ryu et al., 2019; Setiawan et al., 2018; Tibay & Cody, 2021; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Trainin et al., 2018; Truesdell & Birch, 2013
	2) Consider the access and availability of technology in teacher preparation programs and field placements and select devices and programs accessible in the field	Eutsler, 2022; Henderson et al., 2013; Lu & Lei, 2012; Neumann et al., 2021; Rokenes & Krumsvik, 2014; Tiba & Cody, 2021; Voithofer & Nelson, 2021; Zipke et al., 2019
	3) Be aware of PK-12 teachers' technology integration approaches in the field and make connections	Eutsler, 2022; Henderson et al., 2013; Lu & Lei, 2012; Neumann et al., 2021; Rokenes & Krumsvik, 2014; Voithofer & Nelson, 2021
Personalized, researched-based, and equitable	4) Align theory and practice	Aydin, 2017; Baran et al., 2019; Brenner & Brill, 2016; Kale, 2018; Ryu et al., 2019; Sardone, 2019; Setiawan et al., 2018; Tondeur et al., 2012; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Vaughan, 2014
	5) Consider developmental factors for sequencing activities	Brenner & Brill, 2016; Hughes et al., 2016
	6) Rich opportunities for identity construction	Chai et al., 2019; Charbonneau-Gowdy, 2015

Design Principle	Implementation Strategies	Citations
	7) Catering for diversity	Donner & Kumar, 2016; Jones & McLearn, 2012; Voithofer & Nelson, 2021
Explicit and sustained modeling	8) Modeling a variety of technologies	Admiraal et al., 2017; Aydin, 2017; Baran et al., 2019; Bell et al., 2013; Brenner & Brill, 2016; Charbonneau-Gowdy, 2015; Clausen, 2022; Eutsler, 2022; Gawrisch et al., 2020; Henderson et al., 2013; Hughes et al., 2016; Kale, 2018; Lu & Lei, 2012; Neumann et al., 2021; Sardone, 2019; Setiawan et al., 2018; Tiba & Cody, 2021; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Trainin et al., 2018; Truesdell & Birch, 2013; Uerz et al., 2018; Vaughan, 2014; Wetzel et al., 2014; Zipke et al., 2019
	9) Explicit modeling of the utility value of technologies	Admiraal et al., 2017; Brenner & Brill, 2016; Clausen, 2022; Gawrisch et al., 2020; Henderson et al., 2013; Kale, 2018; Lu & Lei, 2012; Trainin et al., 2018; Uerz et al., 2018
	10) Explicitly explain/show the connections to theory	Baran et al., 2019; Brenner & Brill, 2016; Clausen, 2022; Sardone, 2019; Setiawan et al., 2018; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021
	11) Explicitly model content-specific technology integration examples and applications	Admiraal et al., 2017; Aydin, 2017; Baran et al., 2019; Bell et al., 2013; Chang et al., 2012; Charbonneau-Gowdy, 2015; Cheng et al., 2022, Chien et al., 2012; Clausen, 2022; Cydis, 2015; Dorner & Kumar, 2016; Eutsler, 2022; Hsu & Lin, 2020; Hughes et al., 2016; Lu & Lei, 2012; Menon et al., 2018; Neumann et al., 2021; Sardone, 2019; Setiawan et al., 2018; Tiba & Condy, 2021; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Trainin et al., 2018; Truesdell & Birch, 2013; Uerz et al., 2018

Design Principle	Implementation Strategies	Citations
	12) Explicitly cognitive modeling of the decision-making/pedagogical reasoning of technology integration in the field considering contextual factors	Brenner & Brill, 2016; Chai et al., 2019; Henderson et al., 2013; Lu & Lei, 2012; Setiawan et al., 2018; Trainin et al., 2018; Uerz et al., 2018; Vaughan, 2014
	13) Emphasize student-centered benefits of technology integration	Admiraal et al., 2017; Cydis, 2015; Sardone 2019; Trainin et al., 2018; Vaughan, 2014
	14) Explicitly model multiple aspects of technology in teaching and learning	Henderson et al., 2013; Hsu & Lin, 2020; Trainin et al., 2018
	15) Explicitly model technology integration in a social context	Bell et al., 2013; Henderson et al., 2013; Kale, 2018; Lu & Lei, 2012; Trainin et al., 2018
	16) Modeling sustained over time and discipline	Bell et al., 2013; Charbonneau-Gowdy, 2015; Dorner & Kumar, 2016; Henderson et al., 2013; Menon et al., 2018; Trainin et al., 2018
	17) Provide teacher candidates opportunities to critically review and assess relevant resources, curricula, or lesson examples	Aydin, 2017; Dorner & Kumar, 2016; Kale, 2018; Sardone, 2019
	18) Design collaborative activities	Admiraal et al., 2017; Aydin, 2017; Baran et al., 2019; Bell et al., 2013; Brenner & Brill, 2016; Chai et al., 2019; Chang et al., 2012; Cheng et al., 2022, Chien et al., 2012; Cydis, 2015; Dorner & Kumar, 2016; Henderson et al., 2013; Hsu & Lin, 2020; Jones & McLean, 2012; Kale, 2018; Sardone, 2019; Setiawan et al., 2018; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Trainin et al., 2018; Truesdell & Birch, 2013; Vaughan, 2014

Design Principle	Implementation Strategies	Citations
Authentic hands-on assessment	19) Provide teacher candidates with authentic, hands-on learning by design projects focusing on technology integration	Admiraal et al., 2017; Aydin, 2017; Baran et al., 2019; Bell et al., 2013; Brenner & Brill, 2016; Chai et al., 2019; Chang et al., 2012; Cheng et al., 2022, Chien et al., 2012; Cydis, 2015; Eutsler, 2022; Henderson et al., 2013; Hsu & Lin, 2020; Hughes et al., 2016; Jones & McLean, 2012; Kale, 2018; Karaoglan Yilmaz & Durak, 2018; Lu & Lei, 2012; Menon et al., 2018; Neumann et al., 2021; Rokenes & Krumsvik, 2014; Ryu et al., 2019; Sardone, 2019; Setiawan et al., 2018; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Truesdell & Birch, 2013; Vaughan, 2014
	20) Offer teacher candidates explicit evaluation criteria for technology integration in assignments and field experiences	Bell et al., 2013; Dorner & Kumar, 2016; Henderson et al., 2013; Jones & McLean, 2012; Tiba & Cody, 2021; Wetzel et al., 2014; Zipke et al., 2019
	21) Offer teacher candidates ample opportunities for ongoing discussion, reflection, and feedback	Aydin, 2017; Baran et al., 2019; Chang et al., 2012; Cheng et al., 2022, Chien et al., 2012; Donner & Kumar, 2016; Henderson et al., 2013; Hsu & Lin, 2020; Kale, 2018; Neumann et al., 2021; Sardone, 2019; Setiawan et al., 2018; Tondeur et al., 2012; Tondeur et al., 2016; Tondeur et al., 2018; Tondeur et al., 2019; Tondeur et al., 2021; Trainin et al., 2018; Truesdell & Birch, 2013; Wetzel et al., 2014; Zipke et al., 2019
	22) Give teacher candidates opportunities to revise and refine their design	Aydin, 2017; Dorner & Kumar, 2016; Menon et al., 2018; Truesdell & Birch, 2013
	23) Recommend teacher candidates share their projects with others	Aydin, 2017; Wetzel et al., 2014

Design Principle	Implementation Strategies	Citations
	24) Give teacher candidates sustained encouragement	Chien et al., 2012; Tiba & Cody, 2021
	25) Celebrate the learning with stakeholders	Jones& McLean, 2012

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Appendix C
Implementation Strategies Mentioned in the Included Articles

References	Implementation Strategies																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Admiraal et al. (2017)								X	X		X		X					X	X						
Aydin (2017)				X				X			X						X	X	X		X	X	X		
Baran et al. (2019)	X			X				X		X	X							X	X		X				
Bell et al. (2013)	X							X			X				X	X		X	X	X					
Brenner & Brill (2016)	X			X	X			X	X	X		X						X	X						
Chai et al. (2019)						X						X						X	X						
Change et al. (2012)											X							X	X		X				
Charbonneau-Gowdy (2015)						X		X			X					X									
Cheng et al. (2022)	X										X							X	X		X				
Chien et al. (2012)											X							X	X		X			X	
Clausen (2022)								X	X	X	X														
Cydis (2015)											X		X					X	X						
Dorner & Kumar (2016)	X						X				X					X	X	X		X	X	X			
Eutsler (2022)	X	X	X					X			X								X						
Gawrisch et al., (2020)								X	X																
Henderson et al. (2013)		X	X					X	X		X	X		X	X	X		X	X	X	X				
Hsu & Lin (2020)											X			X				X	X		X				
Hughes et al. (2016)					X			X			X								X						

Jones & McLean (2012)							X											X	X	X					X
Kale (2018)				X				X	X						X		X	X	X		X				
Karaoglan Yilmaz & Durak (2018)																			X						
Lu & Lei (2012)		X	X					X	X		X	X			X				X						
Menon et al. (2018)								X			X					X			X			X			
Neumann et al. (2021)	X	X	X					X			X								X		X				
Novak & Wisdom (2018)								X										X							
Rokenes & Krumsvik (2014)		X	X																X						
Ryu et al. (2019)	X			X															X						
Sardone (2019)				X				X		X	X		X				X	X	X		X				
Setiawan et al. (2018)	X			X				X		X	X	X						X	X		X				
Tiba & Condy (2021)	X	X						X			X									X				X	
Tondeur et al. (2012)	X			X				X		X	X							X	X		X				
Tondeur et al. (2016)	X							X		X	X							X	X		X				
Tondeur et al. (2019)	X			X				X		X	X							X	X		X				
Tondeur et al. (2021)	X			X				X		X	X							X	X		X				
Tondeur et al., (2018)	X			X				X		X	X							X	X		X				
Trainin et al. (2018)	X							X	X		X	X	X	X	X	X		X			X				

Truesdell & Birch (2013)	**X**							**X**			**X**							**X**	**X**		**X**	**X**			
Uerz et al. (2018)								**X**	**X**		**X**	**X**													
Vaughan (2014)				**X**				**X**				**X**	**X**					**X**	**X**						
Voithofer & Nelson (2021)		**X**	**X**				**X**																		
Wetzel et al. (2014)								**X**												**X**	**X**		**X**		
Zipke et al. (2019) USA		**X**						**X**												**X**	**X**				

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Appendix D
Guiding Questions for the Design of Modeled Learning Experiences

1. Contextual and Content-Specific Design	
	Do you showcase your content area expertise in your design of technology integration learning experiences?
	Do you consider the access and availability of technology in your teacher preparation program and field placements? Do you select devices and programs accessible in the field?
	Are you aware of PK-12 teachers' technology integration approaches in the field? Do you make connections to those approaches?
2. Personalized, Research-Based, and Equitable Design	
	Does your design of the learning experiences align with theory and practice?
	Have you considered the developmental factors of teacher candidates when sequencing activities?
	Do you provide teacher candidates with rich opportunities for their teacher identity construction?
	Does your design consider and incorporate diversity?
3. Explicit and Sustained Modeling Design	
	Do you model a variety of technologies?
	Do you explicitly model the utility value of technologies (technology being deployed to engage students in active learning that allows them to construct knowledge)?
	Do you explicitly explain and show the connections to theory?
	Do you explicitly model content-specific technology integration examples and applications?

	Do you explicitly provide cognitive modeling of the decision-making/pedagogical reasoning of technology integration in the field considering contextual factors?
	Do you emphasize the student-centered benefits of technology integration?
	Do you explicitly model multiple aspects of technology in teaching and learning?
	Do you explicitly model technology integration in a social context?
	Is your modeling sustained over time and discipline?
	Do you provide teacher candidates opportunities to critically review and assess relevant resources, curricula, or lesson examples?
	Do you design collaborative activities for the peer-to-peer, candidate-to-teacher educator, and preservice-to-inservice teachers' interactions?
4. Authentic, Hands-On Design	
	Do you provide teacher candidates with authentic, hands-on learning by designing projects focusing on technology integration?
	Do you offer teacher candidates explicit evaluation criteria for technology integration in assignments and field experiences?
	Do you offer teacher candidates ample opportunities for ongoing discussion, reflection, and feedback?
	Do you give teacher candidates opportunities to revise and refine their designs?
	Do you recommend teacher candidates share their projects with others?
	Do you give teacher candidates sustained encouragement?
	Do you celebrate the learning with stakeholders?

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