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Approximating Teaching: A Systematic Review of the Research

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Teacher candidates ("candidates") need opportunities for practice during teacher preparation so they can enact equitable, responsive instruction as soon as they enter classrooms. Theory suggests candidates can benefit from "approximating" aspects of teaching in reduced-complexity settings like role-plays, rehearsals, and simulations, where they can receive more support than they might in clinical placements, without risking harm to real students. However, the field needs more clarity about how to leverage approximations in effective and efficient ways that promote candidate learning. To determine which supports contribute to candidate learning from approximations, we systematically reviewed 26 studies that include measures of learning following approximations. We examine the contexts and conditions in which approximations are helpful, with which supports, and toward which goals. Although 23 studies find candidates improve after approximations, there are numerous methodological issues with the research base that limit the claims we can make about the affordances and constraints of different approaches to approximation. Absent empirical clarity, we offer a range of hypotheses we argue can and should be tested systematically through coordinated research efforts. We conclude by suggesting common definitions and variables for future, more systematic research of approximations of teaching.

Keywords: teacher education/development, teacher assessment, teacher knowledge, observational research

How should teacher education programs use the limited time they have to prepare beginning teachers? Most agree that a meaningful portion of that time should

be spent in pre-K–12 classrooms, ideally learning alongside mentors who are skilled at supporting children and novice teacher candidates (termed "candidates") (Goldhaber et al., 2020; Ronfeldt et al., 2018). There is considerably more debate around coursework and whether candidates should dedicate their time to practicing key teaching skills with their peers and instructors or engage in more "traditional" forms of teacher education that emphasize educational theory (for a critique, see Levine, 2006) and the moral and philosophical dimensions of skilled instruction (Fenstermacher & Richardson, 2005; Liston & Zeichner, 1987; Sanger, 2008). The first approach, broadly termed "practice-based teacher education" (PBTE), is the focus of this systematic review. The heart of the PBTE approach is that prospective teachers need more than learning *about* pedagogy; they also need scaffolded opportunities to practice *doing* instructional routines and skills (Ball & Forzani, 2009; Ball et al., 2009), what Grossman et al. (2009) termed "approximations of teaching."

Rather than solely using courses to develop disciplinary content or knowledge of educational theory, PBTE offers learning experiences that help candidates practice instructional activities, like engaging in an interactive read-aloud or facilitating a discussion about mathematical ideas with support from teacher educators (e.g., Lampert et al., 2013). Requiring PSTs to do the skills being discussed in a course helps to address what Kennedy (1999) calls the "problem of enactment," by which candidates can talk about skilled instruction but cannot actually employ those instructional skills in their interactions with students (p. 70).

Of course, enactment happens in clinical placements where candidates practice working with real students, but enactment in coursework has other affordances, allowing teacher educators more opportunities to provide explicit instruction on what Lampert and Graziani (2009) referred to as the "rules of engagement" needed for effective teaching. Because these approximations are inherently artificial, teacher educators can pause instructional activities and ask candidates to analyze aspects of the interactions and reflect on the consequences of their instructional choices (Lampert et al., 2013). In some cases, they can also "try again" in ways that are logistically challenging in pre-K–12 classrooms (Dieker et al., 2014). Instructors can press them to consider how their beliefs, values, and visions for educational equity and justice influence what they do in classrooms (Davis et al., 2017; Dutro & Cartun, 2016; Richmond et al., 2017). In this way, PBTE can afford opportunities to underscore how knowledge, beliefs, and observable skills are intertwined. It can also highlight the interaction between routine features of instruction and the complexity that emerges when these features are combined and situated in the context of real, relational classrooms (Lampert & Graziani, 2009; Lampert et al., 2013).

Though PBTE is not without critics (e.g., Kennedy, 2016; Philip et al., 2019) and is not necessarily a novel idea (Kennedy, 1999; Lampert, 1985; Zeichner, 2012), there has been a proliferation of new scholarship around these ideas since the publication of a series of seminal papers in 2009: Ball and Forzani's paper focused on struggles to articulate the "work of teaching" and associated challenges for teacher education, Grossman et al.'s paper focused on "teaching practice" across a range of professional education contexts, and Lampert and Graziani's work focused on "rehearsals of instructional activities" as a tool for teaching

teachers. Though these ideas around PBTE have been influential in shaping the work of teacher education, there has not been a systematic review of the associated research. First and foremost, we still do not know whether approximations of teaching help launch more skilled teachers. The goals of this systematic review of that literature are to detail what we have learned about candidate development from approximations of teaching, as well as delineate areas where more research is needed.

In addition to providing more synthetic empirical evidence about whether approximations "work" in the ways they are intended, we also wanted to know the contexts, conditions, and corresponding supports that maximize approximations' potential utility. To that end, we also synthesize what is being approximated, by whom, for what purposes, and in what contexts. One of our central motivations is to support teacher educators in making more empirically informed decisions about the affordances and constraints of different approaches to approximating teaching, as well as the degree to which different supports before, during, and after an approximation support improved teacher development. Teacher education is contracted compared to other types of professional education, like medicine, nursing, or architecture. Teacher educators will be better able to capitalize on their limited time with candidates with a clearer sense of the arc of candidate development into, through, and beyond approximations. We answer the following research questions:

1) What practices do researchers and teacher educators approximate? In what contexts are those approximations occurring?
2) What instructional supports do teacher educators provide before and during approximations?
3) To what extent do characteristics of the approximation correspond with development of candidates' knowledge, skills, and beliefs? In what ways does that development transfer to contexts beyond the approximation, including pre-K–12 classrooms?

Given our interest in candidate development, we focus on studies for which there are candidate outcomes, collected before and after an approximation or for which there is a clear comparison group (either no approximation or a different form of approximation), as it is difficult to discern evidence of shifts or growth without comparison. This focus parallels other reviews of research that emphasize the outcomes of specific aspects of teacher preparation (e.g., Mancenido, 2023). Though many important studies have provided fine-grained detail about what can happen *during* an approximation (e.g., Boerst et al., 2011; Davis et al., 2017; Kazemi et al., 2016; Lampert & Graziani, 2009; Lampert et al., 2010; Stroupe & Gotwals, 2018), we were interested in collating evidence about the degree to which and ways in which approximations support candidate learning. We define learning here as observable *shifts* in knowledge, skills, or dispositions in relation to a teacher educator's goals for the approximation.

Background and Framework

The flurry of work on PBTE in the last 15 years has a long history, rooted in conceptual tensions in teacher education around what it means to "practice" or

"try out" engaging in aspects of teaching, which is in itself a professional "practice" (for discussion around the multiple meanings of the word practice, see Lampert, 2010). One of the central challenges for teacher education has been to specify what, when, where, and with whom prospective teachers should practice. Equally important and vexing has been determining when one has practiced sufficiently, and what the role of "practice" should be in the broader arc of learning to be a "practicing teacher." For example, how and when do teachers cultivate content knowledge, productive and justice-oriented beliefs about students, and the theoretical and historical understandings of teaching as a profession (Philip et al., 2019; Zeichner, 2012)? Given the complexity of teaching and the wide array of contexts in which teachers do their work, these are challenging questions without ready answers. This review does not attempt to reconcile these debates, though these questions inform the analyses we describe later.

Rather than serving as spaces for regimented enactment of prescriptive moves like the microteaching research from the 1960s and '70s (for a review, see Grossman, 2005), we argue that approximations can be designed around complex, disciplinary, and justice-oriented practices, allowing candidates to engage in responsive improvisation (Lampert & Graziani, 2009). When Grossman et al. (2009) delineated the value of approximations of teaching, they noted prospective teachers had few opportunities to try out teaching activities during courses, while novices in other relational professions like clinical psychology engaged in myriad role-plays, simulations, and other forms of rehearsal. They also noted that in other fields, approximations were often preceded by or coupled with "representations," opportunities to engage with high-quality models of complex teaching tasks, and "decompositions" that break these complex models into their component parts to identify their key features. Approximations then afford opportunities for teacher educators to provide directive coaching and/or ask the candidate to repeat the practice using a different approach, allowing for collaborative iteration and refinement. Approximations of teaching can also support candidates in framing the work of teaching around issues of race and power, as teacher educators press them to consider how their own identities and students' identities influence classroom interactions (Kavanagh & Danielson, 2020; Stroupe et al., 2020), though this, too, has been contested among teacher education researchers (Cochran-Smith & Keefe, 2022; Philip et al., 2019).

In framing this review, we draw on Grossman et al.'s (2009) description of "pedagogies of enactment," alongside Ericsson and Pool's (2016) theory of the development of professional expertise through deliberate practice. At the outset, we note that we limited our review to research on approximations of teaching that occurred in the absence of real pre-K–12 students, the types of approximations Grossman et al. (2009) and Lampert et al. (2013) would locate on the lower end of the spectrum of authenticity of approximations. We recognize that for most prospective teachers, the most protracted and authentic "approximation of teaching" comes during the semester or year-long student teaching placement working alongside a more experienced mentor. Indeed, there is a rich body of research that analyzes how clinical experiences in pre-K–12 settings serve as crucial, more complex approximations of teaching (e.g., Lampert & Graziani, 2009; Roser et al., 2014).

However, Grossman et al. (2009) also highlighted the particular benefits of "learning to kayak on calm waters" in the less authentic—but more scaffolded—approximations we describe later (p. 2076). By practicing with peers (e.g., through rehearsals or role-plays), actors, or AI agents (e.g., through simulations), candidates independently practice teaching and develop skills or perceptions, with opportunities for more immediate support from teacher educators, without incurring risks to real students.

Teacher educators and researchers may benefit from consistent definitions of approximation types, so that we might learn from others' research on approximations. Thus, we propose specific definitions that could be used for future research, though we note these definitions are not always used consistently in the studies reviewed here. Role-plays are practice opportunities where a candidate assumes the role of "teacher." They may approximate alone or with someone they know (e.g., peer, teacher educator) who assumes a different role for the purpose of the interaction. Rehearsals are similar to role-plays in that the candidate assumes the role of "teacher" and may approximate alone or with others they know. However, rehearsals also include active engagement by a teacher educator or more knowledgeable expert who can pause the interaction, provide feedback on the candidate's performance, and facilitate discussion and reflection throughout (Kazemi et al., 2016). In a simulation, a candidate interacts with an actor rather than practicing alone or with a person they know. There are digitally mediated simulations, like those available through Mursion (e.g., Cohen et al., 2020) and TeachLivE™ (e.g., Driver et al., 2018), in which candidates engage with digital "students" or "parents/guardians" who are remotely controlled by live actors trained to administer scenarios in consistent ways. There are also "standardized student" or live-actor simulations (Self & Stengel, 2020; Shaughnessy et al., 2019) where candidates engage with trained actors.

Approximations as described by Grossman et al. (2009) were not conceptualized as standalone learning experiences. Instead, candidates would approximate teaching practices after engaging with representations of those practices (e.g., video examples, written cases) that teacher educators decomposed into key features. In other words, what happens before the approximation is as vital as what happens during it. These approximations should exist alongside—not replace—other pedagogical approaches that convey concepts, frameworks, and principles, as well as foundational courses that convey the history of pre-K–12 education in the United States and the ways schools perpetuate systemic racism and structural oppression (Zeichner, 2012). Similarly, approximations should complement robust clinical experiences.

The complexity and quality of the practice matter and need to be analyzed vis-à-vis the goals of the practice opportunity (Lampert et al., 2013). An approximation should be sufficiently complex that candidates experience "instructive failure" (Grossman et al., 2009, p. 2078). Along those same lines, the theory of deliberate practice suggests that the quality—rather than the quantity—of practice opportunities predicts learners' improvements; namely, the practice should be within the learner's zone of proximal development (Vygotsky, 1978). While "naive practice" consists of simple repetition, deliberate practice is composed of carefully designed, intentionally sequenced experiences that are just beyond the

learner's comfort zone and coupled with opportunities for feedback. Over the course of a "traditional," university-based teacher preparation program, novice teachers should enact approximations that are increasingly proximal to the demands of classroom teaching (Lampert et al., 2013). A less-advanced novice might read a case study of student formative assessment data and write a script of how they would discuss the data with a student; a more-advanced novice might prepare a brief math lesson and "teach" it to peers before teaching that lesson in a clinical placement.

Theoretically, deliberate practice in an approximation of teaching should build on prior learning by modifying and refining the learner's existing mental representations of teaching. Candidates likely need to first recognize high-quality instantiation of a practice and have its key features highlighted and discussed before attempting enactment (Ball et al., 2009). Teacher educators can support candidates' development of knowledge, beliefs, and skills through a cyclical process that includes multiple opportunities for candidates to learn, practice, and reflect (e.g., Lampert et al., 2013; McDonald et al., 2013). Therefore, what, when, and how candidates approximate must be analyzed alongside what precedes and follows practice, alongside the characteristics of the context in which the practice opportunity is situated (Lampert, 2010).

To that end, our review analyzes the features of approximations in preservice teacher education to build more nuanced theory and/or research-based hypotheses about the characteristics, timing, and supports associated with growth for novices at different stages or contexts of preparation.

Into, Through, and Beyond

As part of their work in the Core Practice Consortium, Grossman et al. (2018) provide guidance for developing and implementing approximations. In particular, we draw on work by Kelley-Petersen et al. (2018) that underscores the importance of analyzing candidate learning in approximations using an *into*, *through*, and *beyond* framework, as well as other work in PBTE that underscores the importance of what is being practiced along with the context in which the practice opportunity is situated (Ball & Forzani, 2009; Lampert & Graziani, 2009; Lampert et al., 2013). These contextual variables include the characteristics of teacher preparation program (e.g., traditional, alternative, online, residency), the licensure area of candidates and the content of the approximation, and the timing in a program in which the approximation occurs. We theorize that the characteristics of the learner interact with the features of the learning experience. As such, we also analyze candidate demographics and other forms of baseline assessment that provide insights about candidates prior to engaging in an approximation (see Table 1 for a visual depiction of the variables we consider as part of our conceptual framework).

First, we consider how teacher educators or researchers prepared candidates going *into* the studied approximation, as well as their goals for candidates' practice—that is, what should be approximated. Some studies in this review align their goals for candidate learning with the Council for the Accreditation of Educator Preparation standards (Regalla et al., 2016). Other research has delineated "core" or "high-leverage" teaching practices as useful foci for approximations (for a

TABLE 1

An Analytic Framework for Incorporating and Studying Approximations

Stage of Candidate Learning	Variables for Future Analysis
Context(s) of Practice	• Characteristics of teacher preparation program(s) (e.g., traditional, alternative, online, residency, licensure area) • Characteristics of candidates (e.g., prior teaching experience, demographics) • Context of approximation within teacher preparation program (e.g., introduced by instructor or researcher, connected to course or program) • Baseline assessment(s) of candidates' focal knowledge, skills, and/or beliefs (e.g., paper & pencil test of knowledge, performance task, survey)
Into the Approximation	• Goals for candidates' knowledge, skills, or beliefs • How candidates prepared for practice (e.g., pre-coaching, collaboration with peers, instruction in a course, other pedagogies of enactment)
Through the Approximation	• Types of enactment (i.e., role-play, rehearsal, simulation) • Modality of enactment (i.e., in-person or digitally mediated) • Structure of enactment (e.g., small group, individual) • Dosage and frequency of repeated enactment opportunities • Availability, modality, dosage, and frequency of instructional supports during the enactment (e.g., pausing, coaching, observing peers, reflection)
Beyond the Approximation	• Instructional supports beyond the enactment (e.g., written reflection, class discussion, post-practice debrief) • Proximal assessment(s) of candidates' focal knowledge, skills, or beliefs
Transfer to Real Teaching	• Distal assessment(s) of candidates' focal knowledge, skills, or beliefs • Enactment of focal knowledge, skills, or beliefs in student teaching • Enactment of focal knowledge, skills, or beliefs in classroom teaching

brief history of this work, see chapter 1 of Grossman, 2018). These include practices that cross content areas, such as eliciting student thinking and communicating with families (TeachingWorks, 2024), as well subject-specific instructional

practices, such as pressing students for evidence-based explanations in science (Windschitl et al., 2012) or selecting and adapting historical sources in history (Fogo, 2014).

Members of the Ambitious Science Teaching Project have also considered *what* teachers should teach, the content and tools that should be considered "high-leverage" (Windschitl et al., 2020). Others, like Stroupe and Gotwals (2018) and Stroupe and Christensen (2023), have built on this work and argued for broadening the goals of approximations to semester-long "macroteaching" rehearsals wherein candidates plan and teach an entire science unit.

Grossman et al. (2009) assert that candidates may experience some modalities of practice as more authentic than others; as such, we note whether practice was digitally mediated and thus designed to feel more realistic and immersive (Dieker et al., 2014) or in-person with other adults playing the roles of pre-K–12 students, parents, and educators (Lampert et al., 2013). We also analyze the type of the approximation (i.e., rehearsal, role-play, and simulation) and practice group size (i.e., individual, small group, and pairs) to understand the design of each approximation and potential for patterns therein.

Though the focus of our review is approximations, we also look for evidence of representations and decompositions as these pedagogies can support enactment in approximations by developing candidates' mental representations or background knowledge (Grossman et al., 2009). We also looked for evidence of other strategies used by teacher educators prior to the approximation to support engagement in it (Lampert et al., 2013). Preparation *into* an approximation can support the efficiency of practice, as novices can expand and refine existing mental representations as they approximate.

We also analyze how candidates in these studies moved *through* an approximation, with particular attention to the design and support of each practice opportunity. Ericsson and Pool (2016) assert that novices learn more from practice when it includes opportunities for immediate and iterative feedback. Support *through* an approximation can help candidates identify the successes, challenges, and implications of their actions during practice. This should, in turn, help candidates when they subsequently engage with real students.

Finally, we analyze how candidates are supported in extending their learning *beyond* the confines of the approximation. Because the goal of approximations is to prepare candidates for subsequent enactment in real classrooms, we analyze the support candidates receive after the approximation to connect their learning to work in pre-K–12 contexts. We also identify the degree to which there is evidence of "transfer" into classroom settings, which we see as the ultimate goal of an approximation.

To the degree we are able, we report on the identities of the learners participating in these approximations and the teacher educators who are facilitating them, but identity is not our focus, because these frames have been used in other synthetic reviews of teacher learning (e.g., Beauchamp & Thomas, 2009; Horn & Garner, 2022). We posit that understanding the features of approximations of teaching that expedite candidates' learning is an important first step in building evidence-based hypotheses to systematically analyze in future work. Future work should also layer hypotheses around identity onto study designs to help us better

understand the degree to which and ways in which candidate and teacher educator identity may influence the enactment and results of different types of approximations.

Researcher Positionalities

As our identities and experiences as teacher educators inform our research, we describe how we position ourselves in relation to this work (Boveda & Annamma, 2023). We bring distinct areas of instructional expertise and research paradigms to this work. All three authors are practice-based teacher educators who work with candidates across grade bands and licensure areas. Consequently, we sought studies that reflect both general instructional skills and content-specific practices. Two authors primarily utilize mixed methods in their research, and one is a qualitative researcher, which contributed to our interest in including *all* available empirical research focused on candidates' learning from approximations rather than focusing on a specific methodological tradition (e.g., Mancenido, 2023). Importantly, all authors have conducted research on approximations of teaching, using a range of methodological approaches. These identities informed discussions of how we conceptualize an approximation of teaching and what we consider observable outcomes of candidate learning.

We engaged in collaborative reflexivity at all stages of the process, from developing research questions and establishing inclusion criteria to coding studies and synthesizing findings (Olmos-Vega et al., 2023). A specific focus was ensuring that our own proclivity toward PBTE did not bias the ways we analyzed these individual studies or the conclusions we drew across them. Systematic coding with defined criteria and multiple coders was helpful in this regard, but we also engaged in group discussions throughout, especially during the synthesis stages of the analytic process (i.e., writing the findings and the implications). It was helpful to have multiple authors with different methodological orientations and a range of lived experiences to surface assumptions and guard against them. Despite our different areas of research and teacher education, we shared a common goal of supporting candidate learning. With this in mind, we analyze the many ways teacher educators support candidates into, through, and beyond approximations of teaching.

Methods

This review examines empirical studies of approximations of teaching used in pre-K–12 teacher preparation programs in the United States. Although teacher educators in many countries—including Israel (e.g., Shapira-Lishchinsky, 2013), Germany (e.g., Martin et al., 2022), and Hong Kong (e.g., Chan, 2022)—utilize and study approximations of teaching, teaching and teacher preparation are cultural activities that can greatly vary by country. For example, McChesney (2010) argues for additional research of teacher education practice in New Zealand, suggesting that the presence of an official, national curriculum means that teacher education research should be particular to their national context. Teacher education pedagogies that contribute to candidate learning in one country may be effective in other countries, but we found little research that examines outcomes of approximations in multiple contexts and no research that examines outcomes for

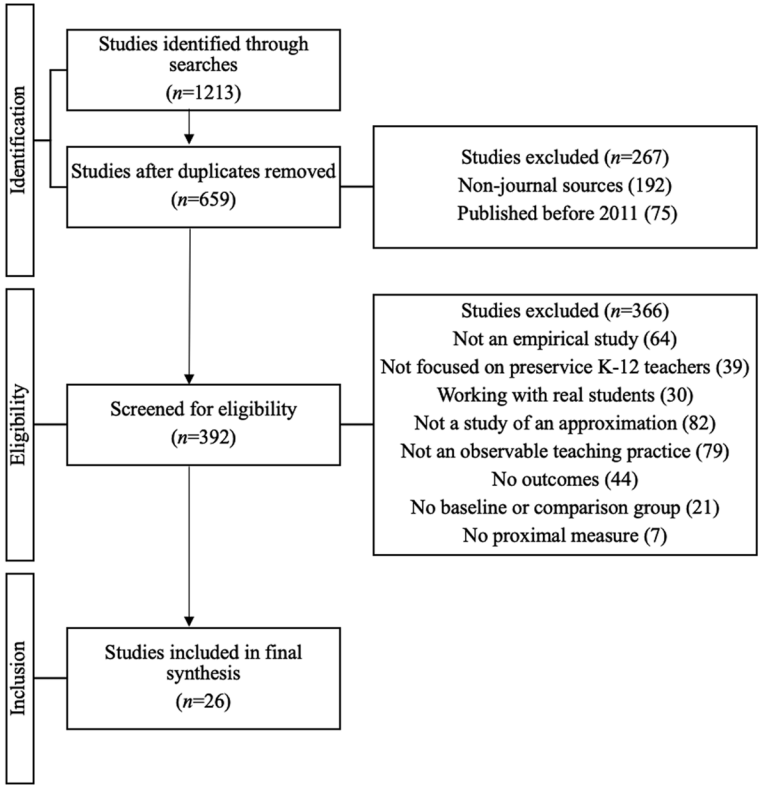

FIGURE 1. *PRISMA flow diagram (Moher et al., 2009).*

candidate learning in multiple countries. Thus, like other systematic reviews about teachers, we limited our search to research on teacher preparation in the United States (e.g., Kennedy, 2016; Mancenido, 2023; Matschiner, 2022).

We analyze studies published since 2011 because we conceptualized Grossman et al.'s work, Ball and Forzani's work, and Lampert and Graziani's seminal paper, all published in 2009, as the key impetus for the body of literature we synthesize. We conducted a systematic literature review using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol as our foundation (Moher et al., 2015). In Figure 1, we provide an adapted PRISMA flow diagram (Moher et al., 2009) to summarize our source identification, eligibility, and inclusion decisions. We document our search, screening, and analytic strategy later.

Search Methods

We exhaustively searched five databases (i.e., Academic Search Complete, Education Full Text [H. W. Wilson], Education Research Complete, ERIC,

TABLE 2

Examples of Search Terms Used Across Databases

Search term category (joined with AND)	Search terms in text (joined with OR)
Type of practice	Approximation of practice, approximated practice, approximation, practice, pedagogies of practice, practice-based, role-play*, rehears*, simulat*, TeachLivE, SimSchool, Mursion, TeachME, TeachSIM, mixed-reality simulation, micro-teaching, authentic practice, Interactive Virtual Training for Teachers
Teacher education	Preservice teacher, pre-service teacher, teacher education, methods course, practice-based teacher education, enactment, core practices

Note. While all terms listed in the table were used, these are provided as examples because additional search terms were included in the search. The asterisk (*) represents a truncated search term; for example, simulat* included simulate, simulated, and simulation.

Psychology and Behavioral Sciences Collection) for all publications relating to approximations of teaching in teacher preparation; we created two sets of search terms and used permutations of each term shown in Table 2 to search the full text of articles in the databases. Our first set of search terms focused on approximations of teaching that teacher educators use to provide novices with opportunities to "take on a more active, and probably more authentic, teaching role" (Grossman et al., 2009, p. 2081). Our second set of search terms narrowed the focus of the search to preservice teacher preparation, as novices across many professions engage in similar practice opportunities. Each set of terms within a specific category can be joined using the Boolean phrase OR; we joined each category of search terms with the search term AND.

Our database search yielded 1,213 records; we saved the authors, titles, publication info, and abstracts of each publication to an Excel spreadsheet. We identified and removed duplicate studies, which resulted in 659 unique articles. We limited our initial review to peer-reviewed articles; we excluded 192 studies published outside of peer-reviewed journals, including unpublished dissertations ($n = 52$) and conference papers or records of proceedings ($n = 90$). Our focus on peer-reviewed work mirrors previously published reviews of research (e.g., Kennedy, 2016; Mancenido, 2023). In addition, while book chapters and dissertations can also be valuable sources of information, they do not always undergo the same level of rigorous evaluation and peer scrutiny as peer-reviewed research articles. Additionally, while we removed studies published before 2011 ($n = 75$), we acknowledge the importance of some earlier research in informing the later design and implementation of approximations of teaching (e.g., McNaughton et al., 2007). Ultimately, these procedures led to the identification of 392 articles

published between 2011 and June 2022, which we systematically reviewed for inclusion or exclusion.

Screening Methods

To determine if the sources would provide insight into our research questions, we read each article that met the initial inclusion criteria. This process led us to refine our inclusion and exclusion criteria further, as shown in Figure 1. Three hundred and sixty-six sources were subsequently excluded for the following reasons:

1. The study was not an empirical study ($n = 64$). This excluded papers that provided conceptual arguments for practice opportunities (e.g., Windschitl et al., 2012), reviewed research relating to practice-based teacher education (e.g., Bradley & Kendall, 2014), and summarized technological innovations that could be used when designing an approximation (e.g., Tyler-Wood et al., 2015).
2. The study was not focused on preservice pre-K–12 candidates ($n = 39$). Studies that reference teacher education but sampled in-service teachers (e.g., Kavanagh et al., 2020) or people who were not training to become pre-K–12 teachers (e.g., post-secondary teaching assistants in Chini et al., 2016) were excluded because they do not provide insight into the integration of approximations in teacher preparation programs. Studies that sampled a combination of preservice and in-service teachers (e.g., Pankowski & Walker, 2016) were included because they examine preservice teacher development.
3. The study measured candidates' work with real students ($n = 30$). Studies of candidates' interactions with real students (e.g., Roser et al., 2014) were excluded based on the specific affordances of practice in the absence of students noted previously.
4. The study did not examine an approximation of practice ($n = 82$). This excluded papers that referenced approximations used within a teacher preparation program but did not conduct analysis specific to an approximation. This criterion resulted in the largest number of excluded studies because it includes studies that mention approximations but focus analysis on other learning opportunities, such as studies of a rehearsal in conjunction with field experiences and coursework as *concurrent* levers for improving candidates' agency (e.g., Ticknor, 2015), studies of teacher educators' instruction rather than candidates' practice (e.g., Kavanagh & Danielson, 2020), and studies that mention an approximation of practice but focus analysis on a decomposition or representation of practice (e.g., Tyminski et al., 2014).
5. The approximated practice was not observable ($n = 79$). We define observable teaching practices as those that an outside observer, such as a teacher educator or instructional coach, can *see* candidates enact. This excluded studies in which candidates write scripted responses for student characters to say (e.g., Amador et al., 2016) and studies in which candidates create a

simulation or game for future students to use (e.g., Schrader et al., 2011). This does not exclude studies that analyzed changes in participants' beliefs, so long as what participants approximated was observable (e.g., Regalla et al., 2016).

6. The study did not include any outcomes of teacher candidate learning *(n* = 44). This excluded papers that described the structural design of a practice (e.g., Boerst et al., 2011), teacher educators' actions (e.g., Kazemi et al., 2016; Lampert et al., 2013), and participants' discourse within an approximation (e.g., Alvermann et al., 2011). Studies excluded under this criterion address what candidates did in the approximation but do not provide evidence that the approximation was associated with shifts in participants' skills, beliefs, knowledge, or beliefs (e.g., Walker & Dotger, 2011). Additionally, studies with outcomes of participants' perceptions of the practice or social validity of an intervention (e.g., Mueller et al., 2019) were excluded unless they also included outcomes for participants' teaching.
7. The study did not utilize consistent measures before and after an approximation *or* use a comparison group to analyze candidates' development (*n* = 21). This excluded studies that detail candidates' actions during and reactions after an approximation of teaching but lack a baseline measure collected before the approximation (e.g., Stroupe & Christensen, 2023; Stroupe & Gotwals, 2018). This also excluded studies that determined outcomes based on measures that did not parallel each other, such as pre- and post-measures of different constructs (e.g., Dalinger et al., 2020; Thompson et al., 2019).
8. The study used distal rather than proximal measures to determine the outcomes of the approximated practice (*n* = 7). These studies were excluded because they used outcomes collected at the beginning and end of a course or semester, rather than immediately before and after the approximated practice (e.g., Bautista & Boone, 2015). It was thus not possible to determine the outcomes of the approximated practice, independent from other instructional activities.

After we used these parameters to exclude studies that were not relevant to our research questions, we included 26 studies in our analysis.

Analytic Methods

We coded each study utilizing 37 analytic criteria that we include in Figure 2. These criteria were adapted from our analytic framework, detailed in Table 1. Eleven of the 37 criteria offered a binary or forced choice option (e.g., the format of the approximation was digitally mediated, in-person, or multiple modalities). More than 70% of the criteria were open-ended, and authors included quotations from each article to respond to the prompt (e.g., explain details of the approximation). Authors entered their codes on a Microsoft Excel spreadsheet, allowing us to include detailed comments and text evidence for each criterion.

Into *Context and Preparation*	What do researchers hope candidates will learn conceptually? What do researchers hope candidates will enact? What is the role of the author? List descriptive information about institution and teacher preparation program. Geographic area of institution? Public or private institution? How many teachers are prepared each year? Who assigned the approximation? Explain details of assignment. When in teacher preparation program did approximation occur? Is there concurrent field placement? Undergraduate, Master's, or licensure-only program? Participant licensure area Sample size Description of candidate demographic characteristics How are candidates prepared for the practice? Does the approximation follow other pedagogies of practice?
Through *Enactment*	Type of approximation (i.e., rehearsal, role-play, simulation) Structure of approximation (e.g., individual, small group) Format of approximation (i.e., digitally mediated or in-person) Explain details of approximation Are there repeated opportunities for practice? What type(s) of instructional supports were available? Who provides the support? When is the support provided?
Beyond *Outcomes*	Is there post-approximation support or debrief? Who provides the post-approximation support? Who participates in the post-approximation support? When does the post-approximation support occur? What is measured specifically to our research questions? How is it measured (i.e., specific scales)? What are the outcomes specific to our research questions? Are tools provided to help candidates connect the approximation to real teaching? Any details of if/how learning transferred to real teaching? Any information of candidates' sensemaking after the practice and post-approximation support?

FIGURE 2. *Coding studies for learning into, through, and beyond approximations of teaching.*

Two authors began the coding process by independently coding one article then meeting to discuss and resolve any discrepancies; this allowed coders to establish intercoder agreement (Campbell et al., 2013). For example, when the authors disagreed about codes related to "post-approximation support or debrief," the authors compared the text evidence they selected before agreeing on activities

that were post-approximation supports (e.g., feedback, self-reflection, small group discussion, whole-class reflection). Following this meeting, the coding authors coded the entire corpus of articles independently. During this process, the coding authors met again to resolve emerging questions about coding, avoid potential coder drift, and ensure alignment throughout the process. After each coding author completed their analysis of each article in the corpus, codes were compared on the Microsoft Excel workbook; the coders agreed on 84.10% ($n = 809$) of the initial codes ($n = 962$). The coding authors met to discuss discrepancies, resulting in 100% coder agreement on the final set of codes.

Limitations

Like any systematic review of research, there are several limitations to our approach. Our inclusion criteria allow for more studies than other recent reviews of teacher education research (Mancenido, 2023) that focus only on causal studies, because we recognize many teacher education researchers engage in self-study and do not always have access to multiple sections of courses to allow for the types of comparison groups required for causal work. However, given our focus on observable development of knowledge, skills, and beliefs over time, we do limit our analysis to studies that include either consistent pre- and post- measures *or* a comparison group. As such, our review does not include many interesting and conceptually rigorous design experiments, in which the approximation evolves in coordination with candidates over an extended period of time, often without baseline measures (e.g., Campbell & Elliott, 2015; Stroupe & Christensen, 2023; Stroupe & Gotwals, 2018) or consistent measures for candidate learning before and after (e.g., Thompson et al., 2019). Moving forward, we hope that more researchers designing and studying approximations of teaching will develop measurement plans that allow for readier assessments of candidate development and learning (for a detailed discussion of some potential approaches, see Hill et al., 2024).

On the other side of the coin, because our inclusion criteria did not limit us to causal studies, we cannot determine whether candidates "get better" because of approximations or particular aspects of the approximation. Studies in this corpus include a range of designs with varying degrees of detail about candidates' preparation for learning and extension of learning beyond approximations. Some included studies use a pre/post design to compare candidates' changes after an approximation to a baseline measure (e.g., Driver et al., 2018). Other studies compare outcomes of an intervention group who approximated to a control who did not (e.g., Mehlig & Shumow, 2013). Others still compare two groups who approximated similar content in different modalities (e.g., Aguilar & Flores, 2022). Unfortunately, it is often difficult to disentangle how other pedagogical approaches leading up to the approximation may contribute to the cited findings in the comparison group approaches. We hope our framework, which attends to the context in which approximations occur and how they are supported by other pedagogies, is helpful for future research. Ultimately, we encourage ongoing work that allows teacher educators to better parse how approximations are situated in broader programs of candidate development, as well as to empirically disentangle how different aspects contributed to such growth.

Finally, we recognize that approximations with students are vitally important for learning to teach. By focusing here on approximations without students, we do not capture the ways in which teacher residencies—for example, scaffold novice teacher learning during classroom interactions (Lampert et al., 2013; Truwit et al., 2024). As an increasing number of novice teachers are prepared in pathways outside of the traditional, university-based programs featured here (Bland et al., 2023; King & Yin, 2022), it will be important to systematically review the evidence about approximations with students in such contexts. We see this as an important direction for future research.

Results

In line with our conceptual and analytic framework, we analyze the context for each study, candidates' preparation *into* the approximation, the design and instructional supports *through* the approximation, and candidates' outcomes and their transfer *beyond* the approximation. Across each, we highlight the variety in this corpus of studies and identify relevant themes for teacher educators and researchers. The following sections are organized to align with our conceptual framework, instantiated by the variables in Table 1.

Context of Practice

Characteristics of Institutions and Teacher Preparation Programs

All studies took place at postsecondary institutions, but studies report inconsistent details about the universities in which candidates are enrolled. Half ($n = 13$) provide no details about the university context, such as size. Eighteen studies did not specify whether candidates were enrolled at a public or private university. Of those that remained, five occurred at public universities and two at private universities; one study (i.e., Kaka et al., 2021) featured candidates from public and private institutions. Two studies (i.e., Edelman & Talbert, 2020; Kaka et al., 2021) included candidates at multiple universities. A plurality of studies ($n = 9$) did not specify the university's geographic region(s), but many occurred in the northeastern United States ($n = 8$).

Most studies detail candidates' licensure area and enrollment program. These details indicate that this research primarily focuses on a narrow subset of licensure programs. More than half ($n = 15$) studied undergraduate candidates. Eight studies exclusively used elementary and early childhood preservice teachers as their sample, whereas only two studies exclusively studied secondary candidates (i.e., Judge et al., 2013; Kaka et al., 2021). Almost all studies examined traditional certification programs; only two included alternatively certified novices in their sample (i.e., Judge et al., 2013; Pankowski & Walker, 2016).

Characteristics of Candidates

The 26 studies included 1,004 unique candidates; sample sizes were relatively small, ranging from 6 (Judge et al., 2013) to 113 candidates (Regalla et al., 2016). Three studies (i.e., Cohen et al., 2020; Regalla et al., 2016; Spencer et al., 2019) investigated samples of 90 or more. Due to the small samples, this research is likely not reflective of the broader population of candidates, who typically number more than 160,000 a year (U.S. Department of Education, 2022).

Studies use a range of categories to describe candidate demographics. Some studies provide rich details, such as neurotypicality (Lamb & Etopio, 2010), relevant work experience (Henry et al., 2022), language history (Driver et al., 2018), or socioeconomic background (Cohen et al., 2020). Among studies that report gender identity and age ($n = 24$), most candidates identify as female and are 18-29 years old. Among those that report race and ethnicity ($n = 13$), most sampled candidates identify as white. One study (Aguilar & Flores, 2022) worked with a population of primarily Hispanic candidates. Few studies noted the inclusion of any Black or Indigenous candidates. While these demographics mirror those of teachers in U.S. public schools (National Center for Education Statistics, 2022), they do not reflect those of pre-K–12 students that candidates are preparing to teach. In the following sections, we do not disaggregate results by candidates' identity, though we theorize this is an important direction for future research.

Context of Approximation Within Teacher Preparation Program

These approximations were most frequently assigned as components of teacher preparation courses ($n = 21$). Others were assigned as programmatic requirements (e.g., Greif Green et al., 2020) or to a random sample of candidates in one program (e.g., Peterson-Ahmad, 2018). Six studies examined approximations that were part of courses on special education (i.e., Driver et al., 2018; Henry et al., 2022; Hudson et al., 2019; McKown et al., 2021; Robbins et al., 2019; Walters et al., 2021). Three studies were associated with a mathematics methods course (i.e., Aguilar & Flores, 2022; Grant & Ferguson, 2021; Lee et al., 2021).

Candidates participated in approximations at varying stages of their programs. Seven studies do not report candidates' progress through their teacher preparation program at the time of the approximation (i.e., Cohen et al., 2020; Greif Green et al., 2020; Judge et al., 2013; Lamb & Etopio, 2020; Lee et al., 2021; Pankowski & Walker, 2016; Peterson-Ahmad, 2018). Fourteen studies described candidates as "upper level," which seems to include second-to-fifth-year undergraduate students. Half of the studies reported candidates had some clinical teaching experience at the time of practice; one study specified that candidates had not begun student teaching (i.e., Robbins et al., 2019). Four studies drew candidates from multiple stages of preparation. Given the widely ranging contexts in which approximations are occurring, we can infer little about the relationship between context and candidates' outcomes.

Baseline Assessment

In 19 studies, candidates completed a baseline assessment before the approximation of teaching practice. These baseline assessments measured candidates' skills, beliefs, and/or knowledge before the approximation, facilitating measures of change after enactment. Researchers also often collected candidates' baseline characteristics for use as covariates; for instance, Cohen et al. (2020) collect "candidates' reported characteristics of the high school from which they graduated, parental education, prior academic achievement (grade point average), and scores on a valid and reliable measure of teacher self-efficacy" (p. 220).

The baseline assessments in these studies varied widely, and some studies collected multiple baseline measures. The most common baseline measure was the

Teachers' Sense of Efficacy Scale (TSES; Bosch & Ellis, 2021; Cohen et al., 2020; Gundel et al., 2019). Five studies measured candidates' sense of "preparedness" or "confidence" relative to the approximated tasks using measures other than the TSES. Other studies used pen and paper assessments to determine candidates' knowledge about certain aspects of teaching (e.g., Ely et al., 2018) or their attitudes toward constructs, such as having a co-teacher (i.e., Spencer et al., 2019). In some studies, the baseline measure was itself an approximation (e.g., Rosati-Peterson et al., 2021), used to discern candidates' level of performance prior to receiving support and/or repeating the approximation.

Into the Approximation

Goals for Practice

We categorized researchers' goals for candidate development in approximations into observable skill development and/or cultivation of knowledge or beliefs. These goals were not mutually exclusive: many studies delineated multiple goals. Nine studies focused on a goal for candidates' knowledge or beliefs, ten studies specified a goal only for skill development, and seven studies specified both types of goals.

Of the 16 that specified knowledge and/or belief goals, most targeted confidence and/or perceptions of preparation for a range of teaching practices. Five studies aimed to develop candidates' perceptions of their skills for communicating with other adults, such as families, co-teachers, or paraprofessionals (i.e., Driver et al., 2018; Henry et al., 2022; Mehlig & Shumow, 2013; Robbins et al., 2019; Spencer et al., 2019). Two studies sought to improve candidates' knowledge, including knowledge of reading strategies (i.e., Ely et al., 2018) and knowledge of a system of least prompts (i.e., McKown et al., 2021).

Of the 17 studies that had a goal for candidates' observable skills, the most common ($n=4$) was improving candidates' behavioral redirection skills (i.e., Cohen et al., 2020; Judge et al., 2013; Pankowski & Walker, 2016; Rosati-Peterson et al., 2021). The second most common ($n=3$) was leading a student discussion (i.e., Grant & Ferguson, 2021; Kaka et al., 2021; Lee et al., 2021). Other observable skill goals ranged widely, including improving communication during collaborative partnerships with families and colleagues (i.e., Driver et al., 2018), responding to bullying in the classroom (i.e., Schussler et al., 2017), and improving feedback to students during a music rehearsal (i.e., Edelman & Talbert, 2020).

How Candidates Prepared for Enactment Opportunity

Grossman et al. (2009) suggest candidates might prepare for practice by engaging with representations (e.g., video examples, written cases) and decompositions (e.g., analysis of component parts of a skill). In six studies, candidates prepared for approximations by viewing representations, such as videos that model enactment of the focal aspect of teaching (i.e., Ely et al., 2018; Grant & Ferguson, 2021; Masters, 2020; Pankowski & Walker, 2016; Walters et al., 2021). Candidates in two studies prepared by first practicing with an additional approximation, such as a role-play or rehearsal (i.e., Aguilar & Flores, 2022; Schussler et al., 2017). Candidates in three studies had multilayered preparation, including opportunities to analyze representations *and* complete an extra

role-play or rehearsal before completing the approximation under study (i.e., Judge et al., 2013; Lee et al., 2021; McKown et al., 2021). In some studies, these opportunities were present, but researchers did not use the specific terms "representation" and/or "decomposition."

Candidates were also prepared through a range of strategies not explicitly connected to pedagogies of enactment (Grossman et al., 2009), such as collaborating with peers (e.g., Grant & Ferguson, 2021) and writing lesson plans (e.g., Edelman & Talbert, 2020). A plurality of studies ($n = 10$) specified that candidates received specific direct instruction through their coursework in preparation. Direct instruction included lectures (i.e., Ely et al., 2018), instructional videos (i.e., Grant & Ferguson, 2021), and content acquisition podcasts (i.e., Kennedy et al., 2015, as cited in Driver et al., 2018) that detailed features of the focal approximation. In one study, candidates did not receive any preparation related to the approximation task; their explicit goal was skill-building through approximated practice and feedback (Rosati-Peterson et al., 2021).

Through the Approximation of Practice

In the following section, we analyze the design of the approximations under study. As described in Table 1, this includes the type, modality, opportunities for iteration through in-the-moment do-overs or repeated practice, and supports available to candidates during the approximation. Across studies, the idiosyncratic goals and contexts make it difficult to discern patterns in what, how, and for what purposes candidates approximate teaching.

Type of Enactment

Authors use the terms role-play, rehearsal, and simulation interchangeably and inconsistently within and across studies to describe the type of approximation. In the absence of uniform terminology, we studied authors' descriptions of the approximation in conjunction with other details about their design. For example, Greif Green et al. (2020) refer to candidates' practice as a "role-play simulation" (p. 42); Lee et al. (2021) refer to a similar opportunity as a "virtual rehearsal simulation" (p. 298). Henry et al. (2022) studied three "simulation conditions": a peer-to-peer role-play, a digitally mediated simulation in which candidates interact with a parent avatar remotely controlled by an actor, and an in-person simulation in which they interact with an actor playing a standardized parent.

Half of the studies ($n = 13$) analyze simulation-based practice. While simulations do not necessarily always leverage digitally mediated interfaces (e.g., Shaughnessy et al., 2019), nearly all of these simulations were digitally mediated (discussed later). Three studies analyzed exclusively in-person approximations, which the authors refer to as rehearsals (i.e., Edelman & Talbert, 2020; Masters, 2020) or role-plays (i.e., Mehlig & Shumow, 2013).

Nine studies featured designs that defied neat classification into "simulation," "role-play," or "rehearsal." Eight of these included analysis of more than one type of approximation, such as a study comparing candidates' performance in peer-to-peer rehearsal with performance in a simulation (Lee et al., 2021, p. 298). One compared virtual reality practice to real teaching in a clinical placement (i.e., Lamb & Etopio, 2020).

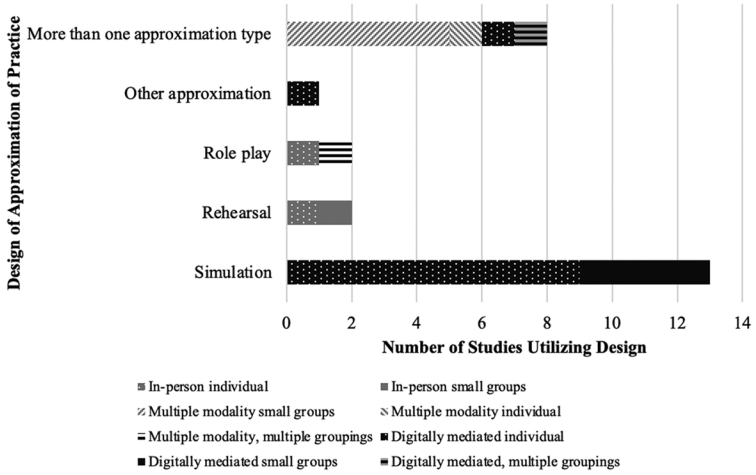

FIGURE 3. *Frequency of approximation designs.*

Modality of Enactment

In addition to classifying studies by approximation type, we considered modality: whether the approximation was in-person or digitally mediated, such as through a mixed-reality simulation (MRS) interface (e.g., Cohen et al., 2020) or an interaction with an AI-driven chatbot (i.e., Schussler et al., 2017). Most studies use approximations that occurred entirely within a digital interface ($n = 16$); seven additional studies analyze approximations in both digital and in-person modalities. We provide an overview of these design aspects and how they relate to approximation type in Figure 3.

Structure of Enactment

Across types and modalities, candidates completed approximations independently, in partners, in a small group, or as a whole class. Because collaboration may influence candidates' development in approximations, we analyzed the size of groups with which candidates practiced. We found that candidates typically completed approximations independently ($n = 14$).

We also analyzed with whom candidates interacted during the approximation, with particular attention to whether the approximation occurred with familiar people (i.e., peers or teacher educators) and/or unknown entities (i.e., actors, digital avatars controlled by actors or artificial intelligence). In most studies ($n = 15$), at least some participants interacted with trained actors, either in an MRS (e.g., Cohen et al., 2020) or in-person (e.g., Henry et al., 2022). In three studies, participants communicated with an interface controlled by artificial intelligence (i.e., Kaka et al., 2021; Lamb & Etopio, 2020; Schussler et al., 2017). One study involved approximating exclusively with known persons (Masters, 2020), and

one asked participants to approximate independently by recording themselves (Mehlig & Shumow, 2013).

When actors or artificial intelligence were involved in approximations, authors often detail the logic of the script governing actors' responses to candidates. For most of these studies ($n = 14$), interactions proceeded according to *If-Then* logics. For example, in Bosch and Ellis's (2021) study, avatar behavior depended on candidates' successful implementation of "classroom management best practices" (p. 22): *If* a candidate used "best practices," *then* avatars responded positively, but *if* the candidates used an "inappropriate strategy," *then* avatars responded negatively. This approach allows candidates to see the potential implications of their instructional choices. Some studies layered additional script logics onto *If-Then*, including standardized planted errors (e.g., McKown et al., 2021; Walters et al., 2021) or increasing complexity or intensity (e.g., Driver et al., 2018). In Hudson et al.'s (2019) study, the *If-Then* logic was replaced by escalation as candidates proceeded through approximation rounds. Specifically, in the third simulation round, student avatars displayed "disruptive behavior" regardless of candidates' instructional choices.

Opportunities for Repeated Enactment

Candidates in most studies ($n = 22$) completed multiple rounds of approximations. In the other four studies, researchers compared candidates' enactment across multiple types of approximations (i.e., Spencer et al., 2019), compared candidates' approximated enactment to enactment in a placement (i.e., Lamb & Etopio, 2020; Masters, 2020), or compared candidates' perceptions of self-efficacy before and after an approximation (i.e., Regalla et al., 2016).

Instructional Supports During the Enactment

In nearly all studies ($n = 22$), candidates had access to instructional support during their approximation(s). Across studies, candidates had 49 distinct supports available, as many studies included multiple instructional supports. The most common forms of instructional support were coaching between rounds of practice (e.g., Bosch & Ellis, 2021), coaching during practice (e.g., Lee et al., 2021), and self-reflection (e.g., Cohen et al., 2020). Some supports were not available to all candidates or were not utilized by all candidates. For instance, Spencer et al. (2019) allowed faculty intervention if students made "a critical error," defined as a "problem that would make the interaction ineffective," but the authors note the support was not utilized (p. 1779). In some studies, particular supports were available to a subset of candidates based on treatment condition (e.g., Edelman & Talbert, 2020; Judge et al., 2013). In some studies, some candidates observed peers' approximations before their own, while others did not benefit from the same sort of previewing depending on their order (e.g., Robbins et al., 2019).

Most instructional supports were available between rounds rather than during the approximations themselves. Only eight studies (i.e., Edelman & Talbert, 2020; Greif Green et al., 2020; Lee et al., 2021; Masters, 2020; Regalla et al., 2016; Spencer et al., 2019; Walters et al., 2021) exclusively offered supports during practice, such as pauses or live coaching. These studies offered a variety of approaches to pausing: candidates determined when to pause (e.g., Spencer et al.,

2019), researchers determined pauses (e.g., Lee et al., 2021), or both could pause (e.g., McKown et al., 2021). Here, too, we are limited in the conclusions we can draw about the utility of different approaches because of the variety in designs and outcomes across studies.

Beyond the Approximation of Practice

Our analysis of candidates' development beyond approximations of teaching explores three questions: What support did candidates receive after their enactment; did they demonstrate improved knowledge, skills, or beliefs beyond the approximation; and did the improvements "stick" beyond the context of the approximation?

Instructional Supports Beyond Enactment

Most studies ($n = 18$) specified candidates received instructional support beyond the enacted practice opportunity. These instructional supports included receiving feedback from a professor (e.g., Bosch & Ellis, 2021) or a peer (e.g., Hudson et al., 2019), completing a self-reflection survey (Edelman & Talbert, 2020) or essay (e.g., Aguilar & Flores, 2022), and debriefing with a small group (e.g., Lee et al., 2021). Candidates sometimes received more than one support after their enacted practice opportunity. For example, participants in Pankowski and Walker's (2016) study watched a video recording of their simulation, rated themselves, responded to self-evaluation prompts, and received feedback from a course instructor after enactment.

Assessments of Teacher Candidate Outcomes

The studies in this corpus have divergent conclusions about how—or if—candidates developed from approximations. As such, we frame our findings of the outcomes following approximated practice in relation to each study's goal(s) for candidates. We define "development" as whether candidates improved in their demonstration of the focal skill, cultivated the desired knowledge, developed the targeted perception, or improved relative to candidates who did not approximate or approximated differently.

Candidates Demonstrated Improvement Relative to Baseline Measure or Comparison Group

Taken together, the reviewed studies suggest approximations of teaching (largely, in this corpus, in the form of digitally mediated simulations) and corresponding instructional support *through* approximations can support candidates' development. In most reviewed studies ($n = 23$), candidates demonstrated improvement after approximating relative to a baseline measure or comparison group. In six of these studies, researchers indicated the improvements were statistically significant (i.e., Driver et al., 2018; Ely et al., 2018; Grant & Ferguson, 2021; Henry et al., 2022; Kaka et al., 2021; Peterson-Ahmad, 2018). Together, these findings suggest approximations can support shifts in candidates' skills, knowledge, or beliefs relating to a variety of aspects of teaching. Later, we detail these studies, grouping them according to our hypotheses about the features of approximations that might support or be relevant to the cited improvements.

Programmatic Context May Influence Candidate Development During Approximations

Several studies explore or compare candidates across different preparation programs (e.g., Kaka et al., 2021; Pankowski & Walker, 2016) or at various stages within one program (i.e., Bosch & Ellis, 2021). Two of these studies suggest candidates' previous or concurrent preparation experiences may influence their development while approximating. Bosch and Ellis (2021) studied candidates at differing stages of one program: candidates in the sample spanned multiple academic years and were enrolled in one of three different courses. Following two rounds of MRS, candidates ($n = 44$) improved overall teacher self-efficacy (Tschannen-Moran & Woolfolk Hoy, 2001) to a statistically significant degree, as well as their self-efficacy in classroom management, instructional strategies, and student engagement. Results did not vary by candidates' academic year but varied based on student teaching experience: candidates who completed the approximation during their student teaching course ($n = 3$) reported decreased self-efficacy for instructional strategies and classroom management. The authors suggest that teaching experience may influence candidates' development during approximations.

Pankowski and Walker (2016) found that candidates pursuing traditional certification ($n = 12$) and alternative certification ($n = 14$) significantly improved their beliefs, knowledge, and enactment of classroom management strategies following six rounds of MRS in which they enacted motivating students and addressing noncompliance. Candidates pursuing a traditional certification were completing field work before student teaching; they found the practice more helpful and realistic than alternative certification participants, who were first-year teachers.

Some studies report findings for candidates in different teacher preparation programs in aggregate. Candidates ($n = 25$) in Kaka and colleagues' study were from three different teacher preparation programs; they completed two rounds of a digital simulation called *Discussion Leader* in which they planned and facilitated a student-centered discussion about contemporary controversial topics. Candidates improved their skills and confidence for leading whole-group discussions about controversial issues to a statistically significant degree, but the results are not disaggregated by program. This parallels other studies that report outcomes by treatment condition rather than programmatic context (Edelman & Talbert, 2020; Greif Green et al., 2020), limiting our understanding of the potential relationship between context and participants' outcomes in approximations.

Candidates May Benefit from Enacting a Range of Instructional Tasks

Across a variety of distinct instructional tasks, candidates who completed approximations of teaching demonstrated improvements. Taken together, five studies suggest candidates can benefit from approximations of a range of teaching tasks (Driver et al., 2018; Grant & Ferguson, 2021; Greif Green et al., 2020; Masters, 2020; Mehlig & Shumow, 2013). These five studies do not allow for claims about the ways other aspects of approximations, such as their modality, context, or instructional supports, influence candidates' development.

Candidates in two studies (i.e., Driver et al., 2018; Mehlig & Shumow, 2013) completed approximations of teaching focused on improving communication

skills with other stakeholders in students' education; these candidates improved after the approximation. While these studies use varying modalities and study designs, both suggest approximations of teaching can be a useful strategy to prepare preservice teachers for this skill. Candidates ($n = 7$) in Driver et al.'s (2018) study individually completed four rounds of MRS in which they aimed to establish collaborative partnerships during "difficult conversations" with colleagues or families (p. 65). They significantly improved their communication skills and perceptions of preparation for developing collaborative partnerships with paraprofessionals, co-teachers, parents, and administrators in an inclusive education setting. Similarly, Mehlig and Shumow (2013) found that candidates ($n = 15$) who were randomly assigned to complete four role-plays speaking to a "parent" reported significantly greater knowledge and skills for communicating with families than candidates in a control group ($n = 19$) who did not practice.

Candidates in two studies (i.e., Grant & Ferguson, 2021; Masters, 2020) completed approximations of teaching focused on content-specific instructional practices and subsequently demonstrated improvements toward the researchers' goals. Candidates in Grant and Ferguson's (2021) study ($n = 59$) individually completed two rounds of MRS in which they led a student-centered discussion to elicit students' thinking about mathematics problem-solving; these candidates significantly improved their confidence in leading a mathematics discussion. Candidates in Masters's (2020) study used a claim, evidence, reasoning (CER) framework to help students interpret data and use it to construct a scientific explanation. When subsequently teaching real students, candidates who completed rehearsals ($n = 8$) performed better at utilizing the CER framework to encourage students' use of evidence to support an argument than candidates who did not do a rehearsal ($n = 8$).

Finally, candidates in Greif Green et al.'s (2020) study practiced supporting students' mental health; the authors find an approximation improved candidates' performance more than business-as-usual preparation for some, but not all, outcomes. Participants were randomly assigned to complete either three virtual role-plays ($n = 24$) or an online training module ($n = 22$) related to supporting students' mental health. Candidates who completed role-plays reported significantly greater feelings of preparedness and confidence to address students' mental health needs compared to candidates who completed modules. Both groups demonstrated statistically significant improvements to mental health stigma–related behavior, and there were no differences between groups. The authors offer hypotheses for the lack of treatment effect on this outcome, including that the measure of mental health stigma they use is not specific to teaching.

Modality of Approximations May Contribute to Candidate Development

Seven studies explore candidates' development across multiple approximation modalities, such as digitally mediated simulations and in-person rehearsals or role-plays. In six of these studies, candidates improved more after digitally mediated approximations than in-person approximations (i.e., Aguilar & Flores, 2022; Lee et al., 2021; McKown et al., 2021; Schussler et al., 2017; Spencer et al., 2019; Walters et al., 2021). The seventh study reported candidates' outcomes after three forms of approximation without examining how the differing modalities may

have influenced candidate development (i.e., Henry et al., 2022). These studies suggest approximations can support candidates' improvements, and some modalities of practice may be more beneficial than others.

Two studies (i.e., McKown et al., 2021; Walters et al., 2021) examined different outcomes for the same sample of candidates; in both studies, candidates completed either two rounds of MRS practice ($n = 12$) or two rounds of live practice with peers ($n = 15$). They practiced enacting a behavioral scaffold called a "system of least prompts" (SLP), which involves a hierarchy of verbal, gestural, physical, or visual prompts. Walters et al. (2021) find that candidates who were randomly assigned to complete MRS ($n = 12$) used the SLP more effectively than candidates who completed rehearsals with peers ($n = 15$). Though both groups showed statistically significant growth between rounds, the MRS group made significantly greater gains. McKown et al. (2021) found comparable levels of perceived knowledge of SLP strategies and confidence in implementing SLP for both groups after the enactment, but they also found that the simulation group implemented the strategies more effectively. These analyses suggest candidates can show greater improvements in skills after completing an MRS compared to peer-to-peer rehearsal, though both modalities may support candidate development.

Three studies of distinct tasks similarly conclude that candidates who complete an MRS demonstrate greater improvements than candidates who complete peer-to-peer approximations. Candidates in Aguilar and Flores's (2022) study individually completed individual MRS leading mathematical discussions ($n = 20$); they demonstrated more effective use of productive mathematical talk moves than candidates who completed in-class rehearsals in groups of four or five peers ($n = 20$). Candidates in Lee et al.'s (2021) study completed two rounds of MRS leading number talks with students ($n = 38$); they significantly increased their use of some talk moves for eliciting student thinking compared to candidates who completed two peer-to-peer rehearsals ($n = 22$). Although candidates in both treatment conditions improved their use of some eliciting strategies between practice sessions, candidates who approximated in mixed reality increased their average use of eliciting strategies more than candidates who completed peer-to-peer rehearsals. Finally, candidates in Spencer et al.'s (2019) study ($n = 48$) who were randomly assigned to complete a conversation in MRS with a special education co-teacher showed significantly greater shifts in their opinions of the value of co-teachers compared to candidates who completed peer role-plays ($n = 42$; Spencer et al., 2019).

One study compared the impact of different approximation opportunities following an in-person role-play (i.e., Schussler et al., 2017). Candidates who completed one in-person role-play with peers followed by virtual role-plays with an AI chatbot ($n = 14$) showed more positive changes in their responses to classroom bullying compared to candidates who completed case study analysis after the initial in-person role-play ($n = 13$; Schussler et al., 2017). The statistical significance of these differences was not reported.

Not all studies that analyzed candidates' enactment across multiple modalities disaggregate findings by modality. Candidates in Henry et al.'s (2022) study individually completed three approximations of communicating with a student's family: a rehearsal with peers, a rehearsal with a parent actor, and an MRS. The

authors find that candidates ($n = 25$) significantly improved their confidence and perception of preparation for communicating with families to a statistically significant degree after the three approximations. The authors report the outcomes in aggregate, so we are unable to identify a relationship between this outcome and the modality of the approximations in this study.

Multiple Rounds of Practice, Opportunities to Observe Peers, and Instructional Coaching May Influence Candidate Development

Eight studies suggest specific supports within approximations might contribute to or bolster candidates' development. In these studies, authors examined candidates' outcomes in relation to a specific treatment or support within the approximation (i.e., Bosch & Ellis, 2021; Edelman & Talbert, 2020; Ely et al., 2018; Gundel et al., 2019; Judge et al., 2013; Peterson-Ahmad, 2018; Robbins et al., 2019; Rosati-Peterson et al., 2021). We categorize these pedagogical supports that may contribute to candidate development into three categories: time spent in the approximation, opportunities to observe peers, and instructional coaching.

Two studies examined the relationship between the amount of time candidates spend practicing and their outcomes (i.e., Gundel et al., 2019; Rosati-Peterson et al., 2021). Candidates ($n = 15$) in Rosati-Peterson et al.'s (2019) study completed three MRS sessions in which they practiced eliciting student thinking through nonverbal questioning techniques. Candidates significantly improved their nonverbal immediacy behaviors (e.g., eye contact, proximity) when responding to students, but these improvements occurred between the second and third sessions; changes between the first and second sessions were not significant. Gundel et al. (2019) similarly examined candidates' outcomes when assigned to varying dosages of MRS: 30 minutes ($n = 20$), 60 minutes ($n = 18$), or 90 minutes ($n = 15$) approximating varying tasks. On average, candidates ($n = 53$) significantly improved their teaching self-efficacy after MRS, but the amount of time seemed to influence their self-efficacy. Participants who practiced for 60 minutes reported a significant decrease in self-efficacy, while candidates who received 30 or 90 minutes of exposure reported significant increases. Notably, candidates in each treatment group were at differing preparation stages, and the tasks of MRS sessions varied across groups, confounding claims about what exactly might be driving differences between groups. Nevertheless, these studies suggest future research should examine the relationship between the amount of time candidates practice parallel tasks and their outcomes.

Three studies examined the influence of peer observations on candidates' learning (i.e., Ely et al., 2018; Judge et al., 2013; Robbins et al., 2019). In Ely et al.'s (2018) study of candidates' knowledge and enactment of collaborative strategic reading strategies (CSR), candidates either approximated using CSR strategies in an MRS ($n = 11$) or observed their classmates' simulated enactment ($n = 11$). Both groups improved their knowledge and enactment of CSR strategies to a statistically significant degree, and candidates in each condition demonstrated statistically similar scores on a subsequent enactment. These findings indicate that both participating in and observing approximations of teaching may support

candidates' development. Relatedly, Robbins et al. (2019) found that candidates who observed peers co-planning a lesson in an MRS before enacting their own approximation performed significantly better than those who did the simulation twice; all candidates ($n = 29$) improved their knowledge of collaboration skills for co-planning. Robbins et al. suggest candidates in the observing group may have experienced "vicarious observational learning" (p. 172); in other words, watching peers practice before approximating seems to have supported their development.

Finally, Judge et al. (2013) examined the influence of peer or instructor feedback on candidates' performance in MRS: candidates who completed three MRS sessions and received feedback ($n = 4$) from an instructor and peers demonstrated more growth in the use of a behavior management strategy than those who received no feedback ($n = 2$), though all groups increased their use of the strategy. The outcomes of these studies suggest observing peers before approximating and/or receiving feedback from peers after an approximation may bolster progress.

Three studies analyzed the impact of coaching on candidates' development during approximations. Candidates in two studies (Cohen et al., 2020; Edelman & Talbert, 2020) demonstrated improvements following instructional coaching. Together, these two studies also suggest limitations to in-the-moment coaching during an approximation. Cohen et al. (2020) studied the impact of self-reflection and two forms of coaching on candidates' behavioral redirection skills, perceptions of student behavior, and ideas about next steps for addressing student off-task behaviors. Candidates who completed a written self-reflection survey between rounds of MRS practice ($n = 33$) demonstrated less improvement than those who received instructional coaching between rounds of practice ($n = 34$), as well as candidates who received coaching between rounds of practice *and* "bug-in-ear" coaching during the first round ($n = 33$). Both coaching groups outperformed the self-reflection group, but there were no differences in outcomes for candidates who received the different forms of coaching.

Edelman and Talbert (2020) also studied the impact of in-the-moment coaching. In this study, an instructor raised a red card to provide visual feedback to candidates who provided vague verbal feedback to an orchestral ensemble of peers during rehearsals. Candidates who received in-the-moment visual feedback ($n = 9$) significantly increased the amount of time their students made music compared to candidates who were randomly assigned to rehearse without feedback ($n = 9$). However, there was no significant difference between groups in the amount of substantive verbal feedback candidates provided.

Not all studies found that instructional coaching improved candidates' outcomes. In Peterson-Ahmad's (2018) study, all candidates ($n = 8$) improved the frequency with which they provided opportunities to respond during four MRS lessons about responsible work habits and respect. A randomly assigned treatment group received coaching after each session, while a control group ($n = 4$) received no coaching; both groups completed self-reflections after each session. Candidates who received instructional coaching showed similar improvements to candidates who did not. The authors do not report on the statistical significance of these results, and they note the small sample size as a limitation. These conflicting

results on the effectiveness of coaching in approximations suggest a need for further research with larger sample sizes and comparably rigorous designs.

Candidates Did Not Demonstrate Improvement Relative to Baseline or Control Group

While 23 studies suggest approximations have the potential to enhance candidates' knowledge, skills, and beliefs, there were three studies where candidates did not improve relative to a baseline measure or control group on any outcome variable(s) after an approximation (i.e., Hudson et al., 2019; Lamb & Etopio, 2020; Regalla et al., 2016). Most such studies employ designs that do not afford causal claims, so we are unable to report on "effects" or statistical significance for many studies. We also acknowledge the publication bias toward findings suggesting growth or change; as such, these studies may not provide an accurate sense of how often or why approximations do *not* contribute to novices' improvement. Here we summarize the outcomes of candidates' development in these three studies.

Candidates in Hudson et al.'s (2019) study ($n = 29$) individually completed three MRS scenarios in which they enacted behavioral redirections for increasingly intense off-task behaviors. Candidates were able to watch peers' approximations but had no other supports available during their individual sessions. After three rounds of MRS, candidates reported no significant changes in their perception of their classroom management ability and reported a decrease in their perception of their overall "teaching ability." The authors suggest this decline in self-perceived "ability" may have occurred because "participants were realizing what they still needed to know to be competent teachers" (Hudson et al., 2019, p. 91). In other words, the MRS exposed candidates to the challenges inherent to teaching.

Candidates ($n = 54$) in Lamb and Etopio's (2020) study were randomly assigned to teach a science micro-lesson about matter and energy in either a clinical context or a virtual reality (VR) student-teaching context. In both conditions, candidates were monitored for physiological measures, such as hemoglobin oxygenation, heart rate variability, and eye movements; university supervisors also evaluated candidates' instruction on a standardized rubric for both conditions. The authors found no statistical difference for the physiological or instructional rubric measures between the treatment conditions, concluding that candidates' physiological and instructional outcomes after three rounds of virtual reality approximation were comparable to those for candidates who practiced teaching with real students. The authors suggest that candidates may experience VR the same way they experience classroom teaching, and VR simulations can provide comparable insight into skill development. The authors note that candidates in either condition may have shown improvement following these opportunities, but the "lack of baseline data from initial entry into the program prohibited assessment of growth" (Lamb & Etopio, 2020, p. 583).

Candidates in Regalla et al.'s (2016) study either completed coursework and an MRS with coaching ($n = 38$) or completed only coursework ($n = 75$) about effective communication with English learners. Candidates in both groups reported statistically similar improvements in attitudes and beliefs related to teaching

English learners on a survey measure. Their findings suggest completing an approximation of practice did not improve candidates' development more than business-as-usual coursework.

Transfer to Practical Teaching

A crucial goal of teacher education is for candidates to transfer their preparation from an approximation of teaching practice to "real" classroom teaching with pre-K–12 students. Very few studies reviewed here explore the degree to which and way in which shifts in observed development after approximations of teaching "stick" across time and contexts. Two studies (i.e., Pankowski & Walker, 2016; Rosati-Peterson et al., 2021) include candidates' qualitative reflections about transfer; they suggest candidates felt able to utilize the behavior management skills they approximated in a clinical teaching context. However, neither study of these studies observes whether candidates' skills transferred to the real classroom context.

Two studies (i.e., Lee et al., 2021; Masters, 2020) observed candidates' enactment with real students after an approximation; both found evidence that candidates transferred skills from approximations to classroom teaching. The designs and approximation outcomes for each of these studies are detailed previously. In their comparison of candidates' elicitation moves in real classroom settings, Lee et al. (2021) found the group that completed a virtual simulation increased their use of all nine elicitation moves between their first approximation and classroom enactment; the in-person rehearsal group increased their use of eight elicitation moves. Though both groups improved, the virtual simulation groups' instruction yielded more student-centered and open-ended discussions. Masters (2020) found candidates who completed in-person rehearsals of instruction on how to construct scientific explanations better supported students in forming claims than a comparison group that did not have practice opportunities. This limited research suggests the need for additional longitudinal research to explore whether and how approximations and corresponding supports can contribute to lasting growth for candidates.

Discussion and Implications

In the last 15 years, there has been a proliferation of research on approximations of teaching that occur outside of pre-K–12 classrooms in the absence of students. It is vital to understand the benefits and drawbacks of such approaches in the current teacher preparation landscape. Ideally, the less authentic approximations we review here serve as a complement or bridge to the more extended and realistic approximation of clinical practice (i.e. student teaching) or serving as teacher-of-record with a skilled mentor, as is more typical in residency programs (Guha et al., 2017; Lampert et al., 2013). However, many of the online-only teacher education programs that have proliferated in recent years do not include *any* clinical practice (Bland et al., 2023; King & Yin, 2022; Kirksey & Gottlieb, 2023), despite strong evidence that high-quality clinical practice can improve novice teacher effectiveness (Goldhaber et al., 2020; Ronfeldt et al., 2018). In such program models, simulations, rehearsals, and role-plays might play an even

more central role in helping prospective students learn how to enact the skills they need to support pre-K–12 students.

The goal of this review was to provide synthetic evidence about whether and how this key aspect of practice-based teacher education has fulfilled its promise of improving teaching. We hoped this work would help move the field of teacher education toward one that prepares candidates through the type of deliberately sequenced and supported practice detailed by Ericsson and Pool (2016) and elaborated as theoretical aspirations in seminal research on teaching and teacher learning (e.g., Grossman et al., 2009; Lampert, 2010). Unfortunately, after careful review of the existing literature, we are left with little clarity. Our initial search yielded many studies that are theory-rich but do not have designs that afford claims about the influence of the approximation on candidates' learning (e.g., Alston et al., 2018; Kavanagh & Danielson, 2020; Stroupe & Gotwals, 2018). The 26 studies reviewed here facilitate such claims through either a pre/post design or a comparison group, but many do not capitalize on theories about how and why approximations support teacher development.

Here, we chart a path forward that would allow for theory building alongside more robust empirical claims. We layer theory onto the empirical findings from this review to make recommendations about how this research might be extended to better speak to policymakers who dictate preparatory program approval requirements. We conclude by highlighting several promising approaches, grounded in the findings of these 26 studies, that could support teacher educators looking for ways to maximize the effectiveness of practice-based approaches.

Tensions for Research and Policy and Next Steps

Several methodological issues limit the conclusions we can make from this review. Though we suggest some tentative hypotheses in the *beyond* section of our findings, we cannot with certainty identify the mechanisms underlying the promising improvements highlighted in many studies. Following, we detail existing limitations and outline next steps for future research. We use our analytical framework as an organizing tool (see Table 1).

The Context of Approximations: Who and When

Most studies featured here include samples of fewer than 60 candidates, who tended to be White and enrolled in traditional, undergraduate elementary or special education certification programs. Few studies featured candidates in secondary endorsement areas or those who were learning to teach in alternative routes, despite growing enrollment in these pathways in recent years (e.g., King & Yin, 2022). The samples in these studies represent only a tiny fraction of the beginning teachers who enter classrooms each year. Given the pedagogical flexibility of approximations, there is reason to believe that they may be useful across a range of preparatory contexts. However, we need far more research in contexts that represent the vast (and growing) diversity of U.S. teacher preparation programs to make nuanced claims about the relationship between learning in approximations and programmatic context. This would include research on approximations in online licensure programs, residency models, and other alternative licensure routes. This also necessitates expanding the study of approximations with

candidates who reflect the diversity we hope to cultivate in the next generation of teachers.

Relatedly, many studies do not detail how the approximation under study was situated within candidates' broader trajectory of learning to teach. It is, therefore, difficult to say whether and how other learning experiences *into* and *beyond* approximations might enhance their utility. More recent research (Bondie et al., 2023; Cohen et al., 2024) and theory (Ericsson & Pool, 2016) suggest that the sequencing of approximations with other learning opportunities may influence candidates' learning. Candidates who are learning to teach in programs that do not culminate in authentic clinical approximations like student teaching or residency will likely need different sorts of enactment opportunities at different time points than the traditional candidates featured in most of these studies. Again, more research across a wider array of contexts is needed to make nuanced claims about the optimal sequencing of approximations.

Wide-Ranging Goals

Across these 26 studies, there is enormous variability in terms of what is being approximated. This suggests approximations are a flexible pedagogy with myriad applications, which can support development across a range of instructional activities from working with parents or guardians to content-generic practices (often behaviorally focused) and more discipline-specific practices like probing students for scientific evidence. However, the variability also reflects underlying tensions in the field about what teachers need to know, understand, and be able to do by the end of teacher preparation. Scholars have made various attempts to delineate the components of teaching considered "most essential for skillful beginning teachers to understand, take responsibility for, and be prepared to carry out" (Ball & Forzani, 2009, p. 504). However, the field is still far from consensus as to which of the many responsibilities of teaching should be prioritized during teacher preparation.

Many studies reviewed here focus on behavior management or dyadic conversations with adults, perhaps because those are more straightforward to approximate, particularly in digitally mediated formats. Much research on approximating complex disciplinary skills has been in the context of rehearsals (e.g., Alston et al., 2018; Davis et al., 2017; Lampert et al., 2013; Stroupe & Gotwals, 2018). We hypothesize that corresponding assessments of candidate development may be more challenging in group rehearsals, which may be why this work is less represented in this review. Much more research is needed to understand how approximations support shifts in content-specific aspects of teaching.

A Need for Shared Language and Measures

It will be challenging to build a more coherent evidence base to address these lingering questions without a set of common measures to use across research efforts. Except for some commonly used survey items, like Tschannen-Moran and Woolfolk Hoy's (2001) Teacher Self-Efficacy Scale (Bosch & Ellis, 2021; Gundel et al., 2019; Regalla et al., 2016), virtually every study uses a unique set of outcome measures about study-specific aspects of teaching. It is worth noting that Ericsson and Pool (2016) define "deliberate practice" as predicated on

coalescence around *what* novices should practice and how one would *know* the novice has developed the requisite skills. Unlike Ericsson and Pool's (2016) research on practice in fields with accepted training methods that have been gradually refined, as in classical music and mathematics, teacher education does not yet agree upon what constitutes "good performance" or how to measure it, making it difficult for teacher education practice to be deliberate.

This review also demonstrates that teacher education needs clear and consistent definitions for different types and modalities of approximation. It is hard to disentangle the contributions of various features to approximations of teaching if we do not use shared definitions of terms and these features. What is a rehearsal versus a role-play? How are they different from simulations?

Teacher education has long faced calls for common language (e.g., McDonald et al., 2013), alongside criticism of such calls (Philip et al., 2019). Without wading into that debate, we argue here that without common language or common measures, it is difficult to build a collective knowledge base about the affordances and constraints of different approaches to approximation for the range of candidates with whom we work (Grossman, 2008).

Efforts like the Annenberg Institute's (n.d.) collection of education-related instruments are a helpful starting place for identifying existing measures with established technical properties, rather than reinventing the wheel with each new study. However, we need more research—and more coordinated research—to better understand how different measures can be used in tandem to provide a comprehensive picture of candidate learning. There is a corresponding opportunity for a repository of approximation materials, collated across live-actor simulations (Self & Stengel, 2020; Shaughnessy et al., 2019), MRS (Mikeska & Howell, 2020) and rehearsals of teaching (Lampert et al., 2013). Having a shared space for defined practices with parallel approximations and outcome measures that could be used with different practice modalities would help in moving us toward a clearer understanding of how, when, for whom, and in what contexts approximations promote candidate development. We see our analytic framework, comprised of variables teacher educators and researchers could consider when designing and studying approximations, as a helpful step in this direction (see Table 1).

Suggested Approaches for Teacher Educators

Despite the limitations noted previously, teacher educators and researchers have made progress on developing, integrating, and studying approximations as a pedagogy of teacher preparation coursework. While we can make few definitive claims from this corpus of literature, we *can* say that it likely matters when, what, and how candidates' approximate teaching in the absence of real students. The supports afforded into, through, and beyond enactment likely also shape candidate development in approximation. In service of providing more concrete recommendations to teacher educators, we layer our conceptual and analytic frameworks onto our empirically grounded findings.

Sequencing Approximations With Other Learning Opportunities

We recommend teacher educators design and implement approximations with attention to their sequencing with other learning-to-teach opportunities. In two

studies (Bosch & Ellis, 2021; Pankowski & Walker, 2016), candidates who completed approximations during or after extensive time in real classrooms did not benefit in the same ways as those without classroom experience. These approximations may not have been appropriately complex for candidates with classroom experience (Grossman et al., 2009). Those with more experience might also need stronger linkages between work in an approximation and work in a classroom (Lampert et al., 2013). Approximations were never conceived as standalone opportunities (Grossman et al., 2009). This means that teacher educators should plan and implement approximations vis-à-vis the rest of the preparatory curriculum, including candidates' clinical experiences or full-time work in real classrooms. This necessitates moving beyond individual courses and instructors as the unit of planning to consider how approximations are sequenced with other opportunities across a candidate's arc of preparation.

Theory suggests candidates benefit from opportunities that are appropriately situated within their zone of proximal development (ZPD; Vygotsky, 1978). In other words, an approximation must be challenging, but not too difficult nor too easy. Identifying a learner's ZPD is challenging, as it is a function of the learner, the task, and the interaction between the two. That said, teacher educators can scaffold tasks in ways that move them into candidates' ZPD by augmenting the approximation with learning experiences *into* and *beyond* it. Almost every study in this corpus indicated candidates received some sort of preparatory support before approximating. Such preparation bolsters schema, or prior knowledge, related to the aspects of teaching candidates will enact (Ericsson & Pool, 2016). These include opportunities to engage with other pedagogies of enactment—representations and decompositions—as well as direct instruction or discussions during coursework.

These studies provided less details about supports beyond the approximation, including strategies for enacting skills approximated in real classrooms with real students. Theory suggests such supports are equally crucial in building enduring and less context-bound knowledge of skills cultivated in an approximation (Ericsson & Pool, 2016; Grossman et al., 2009; Kelley-Petersen et al., 2018). Of the reviewed studies, only one followed candidates from an approximation to parallel work in a classroom (Masters, 2020). Teacher educators should consider how to capture candidates' longitudinal progress as they enact approximated aspects of teachings in new and more complex settings.

Making the Most of Modality

Several studies identified benefits to approximating in digital formats, including mixed reality or artificial intelligence simulations, compared to in-person approximations with actors, peers, or teacher educators (i.e., Aguilar & Flores, 2022; Lee et al., 2021; McKown et al., 2021; Schussler et al., 2017; Spencer et al., 2019; Walters et al., 2021). Prior research suggests digitally mediated approximations may promote the suspension of disbelief better than in-person opportunities, yielding more immersive and authentic practice (e.g., Dalinger et al., 2020). While this is an interesting finding worthy of further research, we acknowledge digital approximations tend to be more resource intensive, demanding more time and money to design and implement than in-person modalities. Though the use of

these technologies is growing, many teacher preparation programs simply do not have access to these novel platforms. As such, we highlight several promising directions to capitalize on these findings while also attending to cost.

What might make digitally mediated approximations different and potentially more useful than interactions with real people? First, in digital modalities, candidates interact with an unknown actor, whereas in-person practice often occurs with peers or teacher educators. Interacting with an unknown person—rather than something about the interface itself—may be the thing that facilitates candidates' suspension of disbelief in ways research suggests are productive for learning (Dieker et al., 2014). It may be harder to embody a "teacher persona" while engaging with a classmate or instructor. In this event, perhaps leveraging unfamiliar counterparts, such as peers or teacher educators from other course sections, could replicate the heightened immersion and embodiment of digital approximations (for strong examples of live actor simulations, see Self & Stengel, 2020; Shaughnessy et al., 2019).

Second, digitally mediated approximations often leverage scripting logics to create intentionally instructive opportunities for candidates, helping them better recognize the implications of their instructional choices. In contrast, role-plays or rehearsals with classmates rely on improvisation and, as such, are not as predictable in terms of the learning opportunities afforded. A peer may be less likely to respond to instruction in ways that reflect pre-K–12 students; they may also be less likely to surface instructive moments that facilitate productive challenge. Importantly, though, such design affordances are not unique to digitally mediated formats. Scripting logics might also be implemented in more standardized, live-actor role-plays, which teacher educators can consistently structure to reinforce learning goals (Henry et al., 2022). Teacher educators might also consider how to layer *If-Then* scripting logics onto peer-to-peer rehearsals so candidates can better see the impacts of their instructional decisions.

Third, we highlight hopeful evidence that candidates can benefit as much or more from watching peers' digital approximations as from doing one themselves (i.e., Ely et al., 2018; Robbins et al., 2019). Relatedly, we see promising results following group practice, perhaps because it affords additional opportunities to see representations of practice in the form of a peer's approximation (e.g., Spencer et al., 2019). By completing approximations in group formats, with group feedback, teacher educators can save time and money.

Finally, we are hopeful that rapid technological advancements will make digitally mediated approximation platforms more accessible, lowering the resource demands of design and implementation. Mursion, the company that administers the mixed-reality simulations featured in many of these studies, is rapidly developing an AI-driven platform that should make these immersive approximations more scalable.

Repetition and Feedback

Nearly every study offered candidates a chance to complete multiple rounds of an approximation. Though we cannot make definitive claims about the influence of repetition or the "sweet spot" for dosage, we see many benefits to offering repeated rounds during approximations. Opportunities for "do-overs" is an

affordance of approximations in the absence of students that cannot often be achieved in clinical placements. Through iteration, candidates can see the implications of different sorts of instructional approaches and decisions. Teacher educators can also compare progress from a baseline approximation to a later attempt, assess growth, and adjust instruction accordingly. If time does not allow every candidate to engage in multiple iterations, these studies suggest the potential for letting peers watch each other's approximations in sequence, picking up on one another's attempts with new approaches.

Importantly, these studies and theories suggest candidates are unlikely to improve through repetition alone (Ericsson & Pool, 2016). These studies add empirical evidence to the theoretical idea that feedback *through* approximations can expedite progress (Cohen et al., 2020; Edelman & Talbert, 2020). Many studies offered feedback through individualized, directive coaching, which is admittedly time and resource intensive. However, it may not have to be. We also encourage teacher educators to consider how to make feedback more accessible to more candidates, such as through group formats or peer feedback. New research has also shown the potential for automated feedback to support shifts to instructional practice—another hopeful direction for improving the accessibility of feedback (Demszky et al., 2025).

Fewer studies in this corpus parsed the relative benefits of different types of *beyond* supports. Nonetheless, we see scaffolding after approximations of teaching as an important means to extend learning beyond the confines of the approximation. These studies use a range of strategies, such as reflections, review of recordings, debriefing, and self-evaluation, to help candidates deepen and solidify their progress following enactment. In our own work, we have been experimenting with providing tip sheets, as well as "feed forward" sessions after approximations to help candidates connect their enactments to more authentic contexts (Cohen, Jones, et al., 2024). Teacher educators are likely using a range of strategies to accomplish similar aims, and we need to capture their utility empirically.

Conclusion

A central tenet of PBTE is that people learn better by doing. Despite the theoretical promise and widespread adoption of practice-based approaches, we still do not know if approximating teaching translates into improvements in teacher development. We return to our motivating question: Do certain types of approximations and accompanying supports help candidates develop knowledge, skills, and beliefs that are important for classroom teaching? This question is at the center of this systematic review and is impossible to answer fully based on the current research. The vast majority of these studies ($n = 23$) note candidate improvement, broadly construed, from approximations. That said, there are numerous reasons why null or negative effects from approximations would be underreported in published studies. There are also numerous methodological issues that mitigate the potential for conclusive claims.

We argue that coordinated research efforts are needed to provide more compelling and nuanced insights that the field of teacher education needs to capitalize on our limited time to support candidate development. In particular, we echo Pankowski and Walker (2016) in identifying the need for more research about

transfer. Most studies ($n = 24$) do not address how—or if—the outcomes of practice "stick" beyond the context of the approximation. The paucity of research on transfer precludes us from answering questions about the longitudinal impact of approximating teaching. Consequently, our understanding of the outcomes of approximations is limited to outcomes that occurred in the context of—and not beyond—the approximations.

This is what we must try to understand as a field: how teacher education pedagogies promote long-term positive outcomes for candidates and, ultimately, the students with whom they will work. While we are unable to make causal claims about the effectiveness of specific supports within approximations of teaching based on the extant research, we find promising evidence that specific supports into, through, and beyond approximations of teaching can promote candidate learning. We return to our analytic framework of variables for teacher educators and researchers to consider when designing and studying approximations of teaching (Table 1). In this review, we have made a start toward better understanding some of these variables, but there is still much to be learned. We hope that teacher educators and researchers can use these variables—and increased attention to the support candidates receive into, through, and beyond approximated practice—to generate more systematic and collaborative work around teacher learning. Working together, we can learn far more than any individual teacher educator in the context of an individual program or course.

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