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Use of Technology in the Preparation of Pre- and In-Service Teachers

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Innovation Configuration for Use of Technology in the Preparation of Pre- and In-Service Teachers

This paper features an innovation configuration (IC) matrix to guide educator preparation professionals in using technology when preparing pre- and in-service teachers. This matrix appears in Appendix A.

Implementing any innovation comes with a continuum of configurations of implementation from non-use to ideal. ICs are organized around two dimensions: essential components and degree of implementation (Hall & Hord, 1987; Roy & Hord, 2004). Essential components of the IC—along with descriptors and examples to guide applying the criteria to coursework, standards, and classroom practices—are in the rows of the far-left column of the matrix. Essential components come from the research. For more information, see this guide describing CEEDAR's standards for selecting essential components. Several levels of implementation are in the top row of the matrix. For example, no mention of the essential component is the lowest level of implementation and would receive a score of zero. Increasing levels of implementation receive progressively higher scores.

ICs have been used in the development and implementation of educational innovations for at least 30 years (Hall & Hord, 2001; Hall et al., 1975; Hord et al., 1987; Roy & Hord, 2004). Experts studying educational change in a national research center developed these tools, which are used for professional development (PD) in the Concerns-Based Adoption Model (CBAM). The tools have also been used for program evaluation (Hall & Hord, 2001; Roy & Hord, 2004).

This tool provides data on the strengths and needs of educator preparation programs (EPPs) that can assist leaders in ensuring that teachers and leader candidates have the necessary knowledge, skills, and practice. The IC in Appendix A of this paper is for EPPs, although it can be modified for PD purposes. Appendix B summarizes evidence-based practices (EBPs) for using technology for preparing pre- and in-service teachers.

Technology Use in the Preparation of Teachers

Technology is a critical component of teacher education and can impact teachers' preparation at the in-service and pre-service levels. Technological developments and upgrades occur continually and rapidly in all fields. How these changes align with teacher preparation is central to this IC. Recent reports show that more than 3.18 million mobile applications are available across various platforms—with new additions and updates regularly occurring (https://www.velvetech.com/blog/mobile-app-update/). This fast and continual development has significant implications for teacher preparation. Faculty members and other instructors in teacher preparation programs must adopt a technology development mindset of rapid iterative development cycles (Ries, 2011) and continuous improvement (Willink & Babin, 2017) to keep pace. Although these tech models are usually associated with product development, these terms also apply to how teacher educators think about integrating and adopting technology. Keeping abreast of emerging technologies and understanding the current state of available EBPs is critical to implementing technology in programs.

Technology use rapidly evolved during the pandemic, with positive and negative consequences. A legitimate criticism is that much of the technology educators used during this time was generic and did not provide specially designed instruction for students with disabilities (Council for Exceptional Children [CEC], 2020). Keefe (2020) noted that the pandemic revealed a need for teachers to gain higher digital competencies. The assumption was that tools were available, but the level of use, ease of use, and capacity of resources (e.g., stable internet) did not always trickle into teachers' repertoires. The role of teacher educators is to ensure coursework and field experiences provide future educators with evidence-based technological, pedagogical, and content knowledge and use emerging technologies that show promise for improving outcomes for students with disabilities.

Adopting and using technology depends on a user's level of knowledge, the interface, sophistication in impacting content, and budget. These variables interact with the user's ability to adapt and learn new technology. Another critical aspect of adopting technology that needs attention is the availability of research evidence and a user's capacity to find, consume, and act on the evidence. Many emerging tools and products lack rigorous testing by independent parties. Numerous reasons exist for this lack of fidelity in research and practice, but the reality is that many consumers will buy and use apps and tools without evidence. Without needing to produce evidence for adoption, developers have little to no incentive to subject their products to rigorous testing that could result in a negative outcome. Scanlon (2021) reports that creating scientific evidence in teacher preparation and using technology is almost impossible with rapid changes in platforms and tools and with infinite options for customization.

The framework for this IC uses a four-quadrant matrix that includes known and emerging tools and approaches available at the time of writing. The authors included various tools and solutions because the field needs to regularly pivot to adopt cutting-edge and emerging technological developments. The authors review each practice, its underlying or emerging research, and its usability in teacher education. The authors also address emerging technology options and reviews of the potential for supporting various outcomes for students with disabilities without a solid research base.

This IC reviews low-level and higher-level tech options for teacher preparation and teaching and presents existing and emerging technologies across four quadrants as an organizational tool for preparation to consider and serve as a roadmap for faculty members at universities of various sizes and resources. The low-tech options include podcasts; case studies; online resources (e.g., IRIS modules); bug-in-ear coaching; and other tech-based coaching platforms. Higher-level tech options include using simulation (e.g., full and mixed reality); artificial intelligence (AI); and machine learning with future technology options, including various types of extended reality (ER) and AI. The authors review existing theories and evidence for each quadrant and recommend how to use them. They note throughout that some universities have a greater capacity for wider ranges of adoption across quadrants given resources, number of faculty members, and other variables aligned with implementing and adopting technology. They also note the need to look at theories around accessibility and the importance of a theoretical framework, such as Universal Design for Learning ([UDL]; Meyer et al., 2014), aligned with adopting and using any technological tool. The same reflection should also align with culturally relevant pedagogy in teacher preparation (Allen et al., 2017).

The authors provide recommendations throughout, with the lens of adoption being that of the faculty members in the teacher preparation programs. They provide clearly **defined practices**, a **summary of existing research**, and considerations for teacher educators to **incorporate practices** into their programs based on reflections within the four quadrants. See Table 1 for the four-quadrant matrix moving from novice to expert teacher and novice to expert technology user or adopter (i.e., teacher educator).

Table 1

Expert to Novice Use: A Grid for Technology Adoption in Teacher Education

	Novice Teacher	**Expert Teacher**
Novice Tech User	**Quadrant 1** · Case studies (video or text-based) · Podcasts · Online resources · Bug in the ear	**Quadrant 2** · Coaching with tagging software · Virtual coaching
Advanced Tech User	**Quadrant 3** · Existing AI · Emerging biometric data · Simulated environments	**Quadrant 4** · Emerging AI · XR, including AR, VR, and MR · Machine learning and multi-modal data

Note: The term *expert* in this paper refers to someone leading the university or school in using technology as an early adopter of new and emerging tools. A *novice* would likely wait to see how others use a technological tool or use a tool because the university or school requires it.

Quadrant 1

Case Studies in Teacher Education

Review of Practice

Case studies are examples of an actual classroom, student, or school-based environment used as an instructional method to help pre- and in-service teachers apply new knowledge within a scaffolded yet authentic environment. The stories about teaching can be short or long, based on information about real students and classroom events, or can be realistic and focus on salient features of school-based problems. Cases can include information to address an authentic problem under consideration or require learners to conduct activities that lead to resolving a problem. Case studies of educational scenarios typically portray dilemma-laden, complex, and dynamic challenges teachers face in their classroom decision-making and provide practice for and models of expert teaching and EBPs to improve student outcomes. The cases also must reflect the culturally relevant pedagogy at the local, state, and national levels for the role for which the teacher is preparing.

Case-based instruction has evolved from paper-based case examples to numerous video-based online case examples from resources such as the Teaching Channel, CEEDAR, and IRIS. Video supports help novices learn new domain knowledge and understand the alignment of high-leverage practices (HLPs) while understanding the processes and procedures of implementation. These representations of practices help provide a shared experience and allow teachers to notice environmental cues under the conditions and cultures in which they apply the new knowledge and skills to reach a desired outcome (Herbst & Kosko, 2014).

Emerging technology, such as 360-degree cameras, can provide a rich image of classroom dynamics and more student-centered and diverse classroom examples to the case study (Walshe & Driver, 2019). Those wishing to move into other more advanced quadrants of technology adoption could consider adding tagging or allowing students to tag videos of targeted practices (see description in Quadrant 2). Video has been a logical and powerful medium for delivering case studies.

Underlying Research

Video case study is interactive, engaging the learner in the activity and giving the learner control (Dieker et al., 2009). The asynchronous properties of a video case study enable the learner to revisit and review aspects of the case to check memory and confirm or refute impressions about new learning (Cognition & Technology Group, 1990), and the video analysis can occur in multiple ways that directly impact student learning outcomes (Morin et al., 2021).

Video can make the covert overt. For example, in the work by Dieker et al. (2009), two teachers in the reading experiment reported that “from watching the video, they learned about nuances of the strategy that were not clear from either reading the book or participating in the training” (p. 188). This “ah-ha” moment when the video reveals to a learner a misconception, misunderstanding, or gap in knowledge that is impeding effective transfer is one of the powers of video; the learner sees all aspects of practice and is not limited by comprehension of text, observation, or the teacher educator’s interpretation. The findings of a systematic review of using video-based programs in mathematics showed a deeper level of noticing, often the highest level of practice competency when employing video-based instruction (Santagata, 2021).

In research and practice, video case studies often contain multimedia aspects and include additional instructional methods and components, such as student data, examples of student work, and communication records between fictional (or real) teachers and parents. In studying video case study, researchers have used instructional groupings that include individuals (Brunvand & Fishman, 2006-2007; Peng & Fitzgerald, 2006); pairs (Daniel, 1996; Herrington & Oliver, 1999); small groups (Barnett, 2006; Kurz & Batarello, 2004; Nagro et al., 2022); large groups (Anderson, 2002); and groups that varied by instructional purpose (Anderson & Bird, 1995; Ochoa et al., 2004; PT3 Group at Vanderbilt, 2003).

Instruction based on video case study has included additional activities, such as in-class discussion (Kurz & Batarelo, 2004; Ochoa et al., 2004; PT3 Group at Vanderbilt, 2003: Schrader et al., 2003); online discussion (Barnett, 2006; Beck et al., 2002; Kurz & Batarelo, 2004; PT3 Group at Vanderbilt, 2003); e-note-taking (Lambdin et al., 1997); lecture (Brunvand & Fishman, 2006-2007; Ochoa et al., 2004; PT3 Group at Vanderbilt, 2003); field experience (Beck et al., 2002; PT3 Group at Vanderbilt, 2003; Schrader et al., 2003); questions embedded in the computer-based environment (Daniel, 1996; Fitzgerald & Semrau, 1998; Koehler, 2002; PT3 Group at Vanderbilt, 2003); face-to-face questioning (Barnett, 2006; Kurz & Batarelo, 2009); readings (Ochoa et al., 2004; PT3 Group at Vanderbilt, 2003; Schrader et al., 2003); writing (Anderson & Bird, 1995; Hewitt et al., 2003; PT3 Group at Vanderbilt, 2003); computer-based quizzes (Fitzgerald & Semrau, 1998; PT3 Group at Vanderbilt); adopting a three-phase sequential approach (Nagro, 2022); and e-coaching (O'Brien et al., 2021).

Fitzgerald and colleagues (2009), using a naturalistic design across five campuses and 10 instructors, found that education students, including pre- and in-service teachers in general and special education, learned best from their computer-based modules when the video case study was used for within-case learning and guided application of case knowledge and skills. Case learning related to accountability and time spent using the materials means that participants were "required to fully complete all embedded activities within the case, and points were given toward their course grade for quality of work" (p. 16). Guided application refers to the built-in mediation and scaffolding within the computer-based environment and is defined as "students were required to fully complete all embedded activities and then apply the information to simulated or real situations as transfer" (p. 16). In relating these findings to face-to-face implementations, the takeaways would be (a) time spent learning, (b) comprehensive engagement in activities around the case, (c) accountability with feedback, and (d) transfer attempts with feedback.

Embedding content into technological tools is easy with various online learning management systems' standardized tools built to use technology to embed cases and content. Regardless of the tool or format, embedding content must be accessible for all learners. Teacher educators need to know and share whether tools are accessible for adoption and instruction.

Usability

Video is particularly useful in teacher education. First, typical university-based teacher education classrooms are often highly decontextualized. Sharing video cases of teachers, children, and classrooms provides a rich and dynamic context for understanding critical special education topics and culturally relevant practices and can bring complexities of teaching and learning into the teacher education classroom. Video also can help analyze simulated experiences (e.g., role-play; Nagro et al., 2022). Alternatively, the video case study can be computer-based and presented as a practice field in which the learner can experience multiple scenarios from multiple perspectives, where the learner must identify relevant information to solve a series of related problems, develop cognitive flexibility, and scaffold transfer (Fitzgerald et al., 2009). Further, some researchers developed video cases to provide explicit models of EBPs, enabling the teacher-learner to observe student outcomes in response to teacher practices and see precisely how to implement the practice with fidelity (Anderson, 2002; Dieker et al., 2009; Nagro et al., 2022). While reviews from other disciplines demonstrate that video increases a novice's ability to notice HLPs (Santagata et al., 2021), how noticing transfers into practice is a difficult research gap to tackle.

General principles that teacher educators need to consider when using and creating video case studies follow. In general, researchers suggest the following:

- Identify an explicit instructional purpose for the use of the video case study.
- Set explicit instructional objectives for intended learner outcomes.
- Select a previously developed video case study based on current learning theory that is culturally relevant to your program.

- Or, if developing a video case study, consider learning theory in its development along with demonstrating UDL principles and culturally relevant practices.
- Choose/develop a narrative video of sufficient duration, complexity, and explicitness to meet the instructional objectives.
- Ensure video case study instruction is adequately mediated, either by the instructor or through the technology, to focus learner attention on the critical aspects of the case.
- Employ multiple scenarios or cases to compare parallel cases to develop cognitive flexibility.
- Engage learners in sustained activities around the case.
- Provide iterative feedback on skills performance, culturally relevant practices, and transfer attempts, enabling learners to revise their efforts based on feedback.

Podcasts in Teacher Education

Review of Practice

Podcast recordings of various topics are a widely accessible resource. They have been used across many areas of higher education, from sports management (Rockhill et al., 2019) to medicine (Kelly et al., 2022) to special education (e.g., Kennedy, Thomas, Aronin, et al., 2014; Peeples et al., 2018). Instructors can easily record regular class lectures and sync the audio track to their slides using Google Slides, Microsoft PowerPoint, Canva, or other low and no-cost programs. Instructors can then easily upload the podcasts to any learning management system (e.g., BlackBoard, Canvas) or a website like YouTube.

Underlying Research

From comprehensive reviews of using podcasts in higher education, researchers have found that most studies evaluated users' satisfaction with podcasts in their courses and improvement in learning and skills (Hew & Cheung, 2013; Kelly et al., 2022; O'Callaghan et al., 2017). Simply recording and posting a lecture online offers teacher educators no guarantee that the resulting podcast contains instructional features (e.g., UDL principles, culturally relevant pedagogy) that augment learning and engagement (Kennedy, Thomas, Meyer, et al., 2014). Generic podcasts are tempting as instructional tools because they are simple for teacher educators to create and easy for students to consume. However, the field of teacher education needs a higher standard of evidence when creating and selecting instructional materials (Kennedy et al., 2015). One research-proven strategy teacher educators can use to move from generic podcasts to an impacting practice is the content acquisition podcast (CAP; Kennedy & Thomas, 2012)

Usability

CAPs combine the typical features of podcasts with visual supports. However, they are more than generic enhanced podcasts, reflecting Mayer's (2020) cognitive theory of multimedia learning (CTML) and accompanying evidence-based instructional design principles. For example, text and pictures presented close to one another limit eye shifting to avoid overwhelming the viewer and limiting their cognitive load. Additionally, steps that align with Mayer's CTML are in manageable pieces to limit cognitive load (view a sample CAP at https://vimeo.com/673745162). On average, CAPs are five to 10 minutes long. They begin with direct instruction on a specific strategy (e.g., modeling), starting with a brief overview of the practice and its relevance and explicit instruction on implementing it. CAPs utilize a strategic blend of clear and well-paced narration, high-quality images, and simple text (e.g., https://vimeo.com/673789095). An embedded modeling video of a teacher using the practice with students in an authentic classroom setting (Kennedy, Hirsch, et al., 2016) is at the end of each CAP recording. A library of CAPs is available for free at spedintro.com. Note that CAPs do not replace course textbooks or lectures; instead, teacher educators can use them to augment and enrich existing instructional methods.

Mayer (2020) posits that multimedia instruction should be designed to maximize learners' available cognitive resources by using visual and auditory inputs concurrently and strategically, not redundantly, which means that in practice, multimedia instruction is a combination of highly scripted narration and carefully selected and arranged images that facilitate efficient interconnectivity between working and long-term memory (Mayer, 2020). The applied arm of Mayer's theory includes his 12 evidence-based instructional design principles (see https://vimeo.com/89716786 for an introduction). Each principle helps instructional designers make good decisions about how and where to arrange images on the screen and how to select, prepare, and organize content within the instructional module.

Research supporting CAPs. More than 30 empirical studies have demonstrated the promise of CAPs in improving teacher candidate knowledge across various practices and special education content (the authors briefly discuss several here). CAPs have been highlighted as a promising practice for delivering multimedia instruction in teacher preparation programs (Sayeski et al., 2015). Further, according to CEEDAR guidelines, CAPs are an EBP. The forthcoming narrative organizes and discusses studies demonstrating the capacity of CAPs to impact teacher candidates' knowledge of content and application of skills.

During the last decade, numerous studies have demonstrated the efficacy of CAPs compared to conventional instructional (e.g., text, lecture) methods. In these empirical studies, CAPs have demonstrated increased learner outcomes (e.g., knowledge, implementation) compared to the conventional methods (e.g., Peeples et al., 2018). In their 2014 study, Kennedy, Thomas, Meyer, et al. investigated using CAPs compared to traditional instructional methods (i.e., text only) on undergraduate candidate knowledge of characteristics of learning disabilities (LD) and autism. Students in courses from two universities were randomly assigned to either the text-only condition (i.e., traditional) or the CAP condition. After engaging with their assigned instructional method, results of a post-test measure of knowledge of disability characteristics demonstrated that candidates in the CAP group made significant gains in their knowledge from pre-test to post-test compared to the text-only group.

In another study, Romig and colleagues (2018) compared using traditional instructional strategies (e.g., practitioner article, lecture) to CAPs on teacher candidate knowledge of self-regulated strategy development (SRSD) in writing instruction. Romig et al. randomly assigned 166 teacher candidates to one of three groups (i.e., practitioner article, lecture, or CAP) to learn the steps of SRSD. After receiving instruction in one of the three formats, candidates completed a post-test measure of SRSD knowledge. Further, candidates were observed using the SRSD steps in a role-play scenario and evaluated using a checklist. Candidates in the CAP group scored significantly higher on the post-test measure of SRSD knowledge compared to the practitioner article group ($p < .001$, $d = 1.51$) and in implementing the SRSD strategy compared to the lecture and article groups.

As Romig et al. (2018) illustrated, CAPs may improve candidate knowledge and the implementation of strategies (e.g., Ely et al., 2014). Peeples et al. (2018) investigated the impact of CAPs and instructor feedback on teacher-candidate use of evidence-based vocabulary instructional strategies (e.g., student-friendly definitions). Candidates ($N = 200$) were randomly assigned to one of three instructional conditions: articles, lecture-based, or CAP. As candidates received instruction in their three groups on evidence-based vocabulary practices, they recorded three videos of themselves teaching vocabulary using the targeted vocabulary practices. After watching each video, researchers provided written feedback only to the article and lecture groups, while the CAP group received written feedback plus a visual of the data. Results demonstrated that the teacher candidates in the CAP/visual feedback group implemented the evidence-based vocabulary practices with a higher frequency and longer duration than the article and lecture groups.

CAPs usability. During the past decade, informed by numerous empirical studies and feedback from users, CAPs have evolved from the originally recorded narration with slides (e.g., https://vimeo.com/72518420) to CAPs with embedded modeling videos (e.g., https://vimeo.com/239507906) to modeling virtual instruction during the COVID-19 pandemic (e.g., https://vimeo.com/448122821). A current library of CAPs (i.e., Project FRaME) funded by the Institute of Education Sciences offers direct instruction to pre-service teachers on evidence-based classroom management practices (see https://vimeo.com/673305723 for example).

Teacher preparation programs utilize CAPs in many ways. Beyond using CAPs to supplement text and lecture-based instruction when initially teaching content, candidates use CAPs to review before exams and as a resource when writing lesson plans and completing other course assignments. Further, teacher educators have assigned candidates to create CAPs as a learning activity. Teacher candidates can then share these CAPs in class to crowdsource their learning.

CAPs are available at no cost through two main venues. First, author Kennedy and colleagues maintain a library of instructional CAPs on www.SPEDIntro.com, including CAPs on various topics of interest to special education teacher educators, researchers, administrators, and teachers. Second, in partnership with CEC and CEEDAR, high-quality CAP-style videos on

HLPs are available at https://highleveragepractices.org/. Both CAP libraries are maintained and updated regularly. As teacher educators consider using CAPs in their courses, the important question for the reader of this IC is how CAPs might be appropriate for pre-service teacher education.

Online Resources

Review of Practice

In a systematic review of teacher preparation in the digital age, one of the emerging competencies for teachers to learn to manage online resources (Starkey, 2020). Teaching online and using the vast online resources can be challenging for teachers and the faculty who prepare them. The field of special education has numerous resources located in the U.S. Department of Education Office of Special Programs (OSEP)-funded centers (https://osepideasthatwork.org/find-center-or-grant/find-a-center), and within these centers are rich resources for teacher preparation online in the long-standing content provided by IRIS; the CEEDAR Center; PBIS; and the Center for Innovation, Design, and Digital Learning (CIDDL), which provides many great examples of how to use various technological tools in teacher education. These resources are an excellent Quadrant 1 tool for implementing in all programs.

COVID-19 created a rapid need for teachers to also support learners with various needs. Implementing online learning requires support from teachers to prepare learning materials; design learning pedagogy; and utilize various digital-based media, such as websites, software, adaptive technologies, and other tools to support the effectiveness of online learning (Reinitz et al., 2022). Students and teachers, pre- and in-service alike, deeply want and need physical presence and want and need flexible online or hybrid technologies. These unique experiences have their own cultures, which play out differently in person or online and impact executive functioning skills (Vasquez & Marino, 2020).

The expanding use of technology-based interventions reflects the increasing role of technology in the lives of teacher candidates and the need to ensure support in using these various environments. To address this expanding need for online teaching and online support in 2020, OSEP funded a new center focused on improving faculty capacity to use educational technology in special education, early intervention, and related service personnel for leadership preparation. The CIDDL's (www.ciddl.org) goals are to increase knowledge, adaptation, and use of educational technology in leadership programs; increase capacity of institutions of higher education; use of educational technology; and sustain professional learning networks.

Underlying Research

The power of technology in improving student learning and engagement is contingent on its effective design and innovative use in various learning environments. The UDL framework provides guidance on designing and using technology that is accessible and supportive of personalized learning experiences for all students, especially students with disabilities (Basham et al., 2020; Meyer et al., 2014). Technologies designed based on UDL, such as digital literacy readers (Dalton & Proctor, 2007; Hall et al., 2015); science notebooks (Rappolt-Schlichtmann et al., 2012); video games (Marino et al., 2011); and podcasts for social studies (Kennedy, Thomas, Meyer et al., 2014), effectively improved performance and engagement for students with disabilities. Meanwhile, the Every Student Succeeds Act stressed the need to support teachers in using technologies consistent with the UDL framework to improve instruction and personalize learning. In addition, the Higher Education Opportunity Act of 2008 highlighted incorporating the UDL framework into teacher preparation and training to support inclusive instructional practices.

Student engagement. Digital technologies have successfully improved the engagement of students with disabilities during ongoing online and face-to-face instructional opportunities across domains through wearable schedule devices (Jimenez-Gomez et al., 2021); augmented reality simulations (Yilmaz, 2016); and self-regulation tools (Crutchfield et al., 2015). As students progress through K-12 schooling, advanced technologies to improve student engagement include instructional gaming (Plump & LaRosa, 2017); mobile devices (Chelkowski et al., 2019); augmented reality (Kellems et al., 2020); and wearable feedback devices (Grawemeyer et al., 2017).

Distance learning. These educational technology tools can be incorporated across curricular domains to support improved outcomes for students with disabilities in elementary to secondary settings as they learn in digital and face-to-face environments. Distance education, including related service delivery, can be provided through telehealth service delivery model settings (Wallisch et al., 2019). Distance learning in K-12 classrooms can be provided through virtual schools, course supplements, in-person offerings, or full-time online classes (Watson et al., 2011). Distance learning provides flexible materials and delivery formats to effectively support students with disabilities in K-12 classrooms through personalized learning experiences (Basham et al., 2017). Distance and online learning results in (a) higher levels of parent-reported competence in supporting their young children's needs compared to face-to-face services (Behl et al., 2017) and (b) greater improvements in student performance compared to in-person classrooms, although these differences are greatest when hybrid options are available (Means et al., 2010). Ulum (2021) reviewed empirical studies by content areas and found that the effect of online education on academic achievement does not differ according to the content areas reviewed (e.g., mathematics, science, social studies, English). Ulum also found that the effect of online education on academic achievement does not differ according to online approaches (e.g., computer-assisted learning, online learning environments, blended learning, mobile learning, web-based learning, social networks). Table 2 provides a list of EBPs in online learning frameworks.

Table 2

Evidence-Based Practices in Online Learning Conceptual Framework

Research Category	**Features**	**Examples**
Content area	· Subject-area contingent · Domain specific	· Reading, math, science, art, etc.
Instructional design	· Taxonomy based (e.g., Bloom's taxonomy or structure of observed learning outcomes)	· Direct instruction or inquiry-based instruction · Motivation: Attention, relevance, confidence, and satisfaction (ARCS) model or behavioral model
Interactivity	· Feedback · Connection type	· E-mail or voice · Synchronous chats · Grading · Opportunity for learning reflection · Blogs · Social media
Usability	· UDL framework · Accessibility	· Multiple methods of presentation · Multiple methods of expression · Multiple methods for engagement · All content accessible for people with exceptionalities

Usability

Effective usability and interactivity in any learning environment include creating a positive learning environment by cultivating self-efficacy and providing meaningful and active engagement, culturally relevant pedagogy, and inclusivity. Instructors of online learning programs should think about how to use best practices in online learning to ensure outcomes for teacher candidates while modeling best practices for online learning. Key variables to consider in modeling are as follows:

- Ensure communication between faculty and students is constant and effective, including e-mail, web-based conferencing (webinar), blog postings, online discussions, and phone contacts. Zoom, Teams, FaceTime, Skype, or Google Meets should be included for students who need a personal approach.
- Provide cooperative learning opportunities to facilitate critical thinking, brainstorming, problem-solving, study groups, and using dyads and peer assessment activities in many online learning environments.
- Provide experiential and active learning activities, utilizing Bloom's Taxonomy and the Theory of Engagement to activate areas of the brain responsible for higher-order thinking and active learning that address the construction of knowledge through analysis, synthesis, and evaluation. These engaging and higher-order activities require pre-service teachers to make decisions, conduct experiments, and explore culturally relevant pedagogy and ways to solve real-world problems through case studies and scenarios to promote a higher level of knowledge achievement and potential learning transference.

- Give punctual feedback regarding students' posts within blogs or through e-mail, assignment postings, or whatever the teacher and students agree on. Structure opportunities for practice and establish peer tutoring when necessary.
- Express high expectations of students by continually motivating, commending successes, and providing stimulating activities to support active learning.
- Embrace cultural diversity. Provide differentiated and culturally relevant instruction by considering all students' needs so all learners can develop to their fullest potential.
- Discuss and define course policies, teacher expectations, and plagiarism early in the course. Differentiate intentional and unintentional plagiarism. Implement contractual documentation, if necessary.
- Ensure accommodation of learners who need special assistance and assistive technologies.

Bug-In-Ear (BIE) Technology

Review of Practice

Feedback is a "crucial and powerful instructional technique to improve knowledge and skills within a wide range of educational contexts" (de Villiers, 2013, p. 66). In EPPs, coaching and supervision are typically provided by a master teacher, eCoach, peer, supervisor, or administrator who oversees teacher candidates' performance and provides specific feedback as they practice applying newly learned knowledge and skills during clinical experiences. The technological component, commonly referred to as Bug-in-Ear (BIE), allows coaches and supervisors to provide discreet feedback to teacher candidates in real time, rather than after the fact, to positively impact the teacher candidate's performance and their P-12 students' performance (Horn & Rock, 2022; Wake et al., 2017).

More than seven decades have passed since Korner and Brown (1952) introduced an on-site BIE device consisting of a miniature, concealed, wired radio transmitter and receiver to provide immediate feedback when supervising clinical psychology students and interns. Fast forward 56 years, Scheeler and colleagues (2006), relying on a personal FM system, ushered in a wireless version of on-site BIE technology to provide immediate feedback while supervising special education teacher candidates. More recently, Rock and colleagues (2012, 2014) developed online BIE using mobile and internet technology to provide discreet, real-time feedback to special education teacher candidates.

Because of increasing online undergraduate student enrollment (National Center for Education Statistics, 2022), one notable benefit of online BIE technology is that it allows an eCoach or supervisor to provide teacher candidates with discreet, real-time feedback during practice-based clinical experiences from anywhere at any time. To date, widespread use of on-site and online BIE is evidenced by adoption and use in more than 12 states (Bouffard, 2020).

Many people ubiquitously use the components that make up online BIE technology, such as Bluetooth earpieces; EarPods; videoconferencing platforms (e.g., Zoom, Microsoft Teams, Skype); mobile devices; and desk or laptop computers. As such, putting them together to provide online BIE coaching and supervising in real time is no longer futuristic; it is familiar (Rock, 2019). Technology know-how demands on users are reduced further when using on-site BIE technology, such as two-way radios. Consequently, in this IC, the authors situate BIE technology in Quadrant 1, as it is well suited for novice technology users. Also, BIE coaching and supervising aligns with novice teacher candidates because the technology allows the eCoach or supervisor to provide immediate feedback that supports transferring newly learned EBPs, high

HLPs, and assessment practices during real-world or simulated clinical practice without interrupting classroom instruction (Rock, Gregg, Gable, & Zigmond, 2009; Horn & Rock, 2022).

Underlying Research

Based on the most up-to-date meta-analyses (Schaefer & Ottley, 2018; Sinclair et al., 2020) and literature reviews (Randolph & Brady, 2018), researchers concur that BIE is an EBP for providing discreet feedback to teacher candidates. Specifically, researchers have effectively used online and on-site BIE when coaching and supervising teacher candidates in K-12 special education (Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014; Scheeler et al., 2006, 2012); general education (Hollett et al., 2017); and early childhood special education (Coogle et al., 2018, 2015). Across BIE studies, researchers have confirmed improvements in teacher candidates' use of evidence-based instruction (e.g., Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014; Scheeler et al., 2006, 2012; Stahl et al., 2016) and positive behavior support practices (e.g., Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014), as well as effective communication strategies (Coogle et al., 2018, 2015). BIE researchers have also reported benefits in P-12 student performance, including high engagement rates (Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014) and expressive communication improvements (Coogle et al., 2018).

Researchers have further demonstrated that BIE feedback shared in real time with teacher candidates can facilitate critical reflection (Nagro et al., 2022), namely a cycle of "in action" reflection (Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014), a hallmark of effective teaching (Schon, 1987). Stahl et al. (2016) used BIE to increase teacher candidates' confidence, resilience, and efficacy and to foster a disposition toward continuous improvement. Other investigators have documented the social validity of BIE (Ottley et al., 2015; Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014; Wake et al., 2017), confirming that most teacher candidates viewed the BIE feedback and coaching they received as comfortable, feasible, and often preferable to delayed feedback, as it allowed them to change their practice immediately. Notably, researchers have confirmed that online BIE technology is dependable, with minor technology disruptions (e.g., Internet outages, connectivity issues, audio or video problems) occurring less than 8% of the time (Rock et al., 2012).

Usability

Technology considerations include BIE devices and equipment, digital access, technology know-how, support, and knowledge and skill in providing and receiving immediate feedback during coaching and supervising (Horn & Rock, 2022; Rock, 2019). BIE equipment varies with options (see Table 1). Although technology has advanced rapidly, online BIE technology has remained affordable and relatively unchanged. The cost of Bluetooth earpieces and a wide-angle web camera or lens comes in at approximately $125 per unit; however, costs vary and can increase depending on the technology (Horn & Rock, 2022; Rock, 2019). To address long-standing digital divides (Adams Becker et al., 2018), EPP professionals can purchase BIE technology through grants and private donations that teacher candidates can check out in person or online at no cost (Horn & Rock, 2022).

Implementation Considerations

Based on the BIE research, the authors offer the following five considerations for incorporating BIE technology into EPP methods, courses, and clinical experiences.

1. When engaging in curriculum scaffolding and spiraling, consider the continuum of pedagogies for HLPs (Brownell et al., 2019) to ensure cohesive and continued course and clinical experiences in which eCoaches and supervisors use BIE technology to provide

teacher candidates with performance feedback based on various targeted practices, rather than fragmented, isolated sessions.

2. Be intentional about planning for and carrying out orientations for eCoaches, supervisors, and teacher candidates and consistently use the coaching and supervising cycle, which includes engaging in pre-BIE session planning, providing BIE real-time feedback during practice-based instruction, and offering post-BIE debriefing (Regan & Weiss, 2020). Importantly, determine how eCoaches and supervisors will provide (e.g., running commentary, keywords or phrases, codes) and differentiate BIE feedback during early, mid, and late clinical experiences (Horn & Rock, 2022). Further, ensure ongoing professional learning and development opportunities for eCoaches and supervisors (Weiss et al., 2020) to ensure, in part, that BIE feedback remains positive and constructive (Horn & Rock, 2022).
3. Secure budget and infrastructure that supports initial and ongoing BIE technology purchases, professional learning, and technology services (Horn & Rock, 2022).
4. Prepare teacher candidates for BIE experiences. Hollett et al. (2017) reported that some teacher candidates found initial BIE feedback distracting, whereas others noted heightened anxiety (Rock, Gregg, Thead, et al., 2009; Rock et al., 2012, 2014). The good news is that distraction and anxiety decrease in three to four sessions (Horn & Rock, 2022; Rock, 2019).
5. Ensure privacy and confidentiality by using three-factor identification, enabling firewalls and encryption, and securing EPP and school district permissions (Rock, 2019).

Although these considerations might seem overwhelming, we encourage EPP professionals to remain steadfast in making this vital undertaking a reality. Integrating BIE technology (see Table 3) to support coaching and supervising in EPPs aligns with the science of deliberate practice (Brownell et al., 2019; Ericsson et al., 1993) and with prevailing professional standards, such as CEC's (2020) transition from knowledge to practice-based professional standards and the American Association of Colleges for Teacher Education's (AACTE, 2018) and the Council for the Accreditation of Educator Preparation's (Council for the Accreditation of Educator Preparation [CAEP], 2022) increased emphasis on clinical experiences (Horn & Rock, 2022). Digital-age teacher candidates and the P-12 students they are learning to teach deserve no less (Rock et al., 2016).

Table 3

Examples of BIE Technology Options

eCoach or Supervisor	**Teacher Candidate**
Online options Devices: · Mobile phone or tablet *OR* lap or desktop computer · Headset (wired or wireless), Bluetooth earpiece *OR* EarPods · Wide angle web camera for mobile phone or tablet *OR* lap or desktop computer Video calling or conferencing platform Examples include: · FaceTime, Skype, Zoom, Microsoft Teams, WebEx	Online options Devices: · Mobile phone or tablet *OR* lap or desktop computer · Bluetooth earpiece *OR* EarPods · Wide-angle web camera for mobile phone or tablet *OR* lap or desktop computer Video calling or conferencing platform Examples include: · FaceTime, Skype, Zoom, Microsoft Teams, WebEx
On-site option · Two-way (wired or wireless) radios with microphone	On-site option · Two-way (wired or wireless) radios with audio receiver

Note. See additional examples in Horn and Rock (2022) and Rock (2019).

Quadrant 2

The ideas in Quadrant 2 are for novice teacher users in teacher preparation, but for pre- or in-service teacher educators who have skills beyond "Googling." These ideas align with feedback and expanding the work already heavily researched in Quadrant 1 but pushing into areas using additional tools in teacher preparation with candidates ready for deeper learning through existing and emerging technology.

Targeted Coaching: Virtual Coaching and Tagging Software

Review of Practice

During the pandemic, virtual "everything" emerged in online environments. This idea of coaching and tagging video for feedback is built on the strong foundational research provided from the practices noted above in Quadrant 1 to expand on those ideas using emerging tools in tagging teachers' performance. Much of the work by researchers in BIE (Horn & Rock, 2022; Scheeler et al., 2006; Wake et al., 2017) provides a strong foundation for the emerging virtual coaching and supervision. This same tagging could occur in a virtual or simulated environment but most often occurs in a video-recorded session.

Underlying Research

In a systematic review of the literature on this topic, Baecher and colleagues (2018) found that video is most often used for reviewing self or a peer in teacher preparation programs, often with an expert or teacher educator facilitating. The presence of a teacher educator and a teacher candidate simultaneously can be problematic and is one of the reasons tagging tools can be helpful. Early work in tagging video resulted in a tool called Video Ante (Ruebe & Gallowy, 2013). This tool was free to use in programs, but no clear research regarding its use emerged.

Authors Kennedy and Dieker respectively received OSEP Stepping Up grants to create Open Education Resources (OERs), which are free tools to help tag and target specific skills in special education. Kennedy's team developed the COACHED suite of evidence-based multimedia PD tools (www.coached.education.virginia.edu) to provide teacher educators with scaffolded observational tools, automated yet customizable feedback, visual data outputs, and teacher candidate self-reflection. A recent article by Kunemund et al. (2022) includes a detailed description.

Dieker's team focused on tagging software aligned with helping STEM coaches work with special education teachers in meeting the HLP goals (CEC & CEEDAR, 2017) and harnessing searchable online resources (e.g., from IRIS Center, National Center for Teachers of Mathematics, Teaching Channel). The authors share examples of each project, which are only two of the numerous Stepping Up projects funded by the USDOE that provide "free" technology resources in a plethora of areas in special education. These two tools specifically focus on video tagging; numerous other tools align with coaching and student learning.

Before sharing specific information about each of these projects, teacher educators should explore other commercial tools already available, depending on feasibility. Tagging software can provide virtual and real-time conversations about performance. The most notable tools currently available are Go REACT, Classroom Mosaic, and BACOT. These app- or subscription-based tools provide various features for providing feedback (e.g., specific student tracking, oral feedback, written feedback) and should be considered by need, program outcomes, and cost. Beyond emerging commercial products, the two different tagging tools are being studied and developed at this time. These tools are in Quadrant 2, as they are meant to make the job of feedback, observation, and reflection with pre- and in-service teachers easier. They do not require knowledge from the user and the teacher about video files and the toolkit aligned with those files.

COACHED

For the past decade, author Kennedy and colleagues have engaged in a collaborative program of research and development focused on multimedia PD to improve teacher candidate quality and outcomes for students with disabilities. The fully operational COACHED web app (www.coached.education.virginia.edu) has four main components: (1) The Classroom Teaching (CT) Scan, (2) automatically generated yet customizable feedback form, (3) data dashboard, and (4) multimedia PD vignettes (e.g., CAPs).

COACHED Component 1: The CT Scan

The CT Scan is an online, low-inference observation tool that provides an observer a way to reliably and flexibly capture instructional practices a teacher uses during a lesson. The CT Scan reflects the behaviorist process product tradition of teaching and learning (e.g., Greenwood et al., 1994) and is well-suited to capture individuals using EBPs in general and special education settings.

The CT Scan captures numerous pieces of information in real time. For instance, the observer can record the broad category of instruction and specific practice the teacher is using and “look for” (implementation markers) for each practice. The CT Scan also allows the counting time stamping and rate per minute for opportunities for students to respond (OTRs), praise statements, precorrection prompts, and student behavior. The data related to the practice are overlaid with what the students are supposed to be doing (e.g., listening, taking notes); instructional grouping size (e.g., small group); co-teaching model; percentage of students who are engaged; specific terms or content that are taught; and visual aids used. Finally, the observer can record qualitative, time-stamped notes. Once a lesson is complete, CT Scan data are automatically presented in written form on the Coaching Feedback Form.

COACHED Component 2: Coaching Feedback Form

One of the biggest barriers to the scalable use of the CT Scan when it was first created was the difficult and time-consuming task of translating observational data into meaningful feedback. A major innovation of COACHED is its functionality to automatically translate CT Scan data into editable, pre-written feedback sentences that populate within the coaching form. COACHED analyzes each practice used and the specific implementation markers of that practice to see if they were checked as observed. If the marker was observed, the program randomly selects a pre-written feedback statement praising the teacher and reinforcing why its continued use is critical. If not observed, a pre-written statement is selected that indicates the teacher should work toward using that practice element and provides a rationale for its importance. This process is replicated for every marker for each practice used. Multiple versions for each implementation marker prevent redundancy for the candidate, as COACHED randomly selects feedback statements tied to each practice/implementation marker. Autonomy still lies with the observer, who can edit feedback before sending it to the teacher. At the bottom of the feedback form, observers can write a summary of the lesson and generate a data-based goal for the teacher.

COACHED Component #3: Data Dashboard

COACHED contains a data dashboard for teachers and others to easily upload to watch their observation videos and access CT Scan data, coaching feedback forms, and assigned multimedia vignettes to watch as PD. The data dashboard is the main method through which observers share data with teachers.

Evidence for CT Scan and Coaching Approach. Researchers and teacher educators have used the CT Scan in numerous research studies and applied settings. Kennedy and colleagues (2018) used the CT Scan as both a dependent measure and an element of their coaching approach in two studies evaluating the impact of a multimedia PD process on inclusive middle school teachers' vocabulary instruction. In both studies, the teachers made significant gains in the quality and quantity of the vocabulary instruction they provided to students with disabilities following coaching using CT Scan data and associated coaching reports. Social validity data revealed teachers' overall satisfaction with this style of data-informed and non-biased coaching and preferred it to checklist-based coaching and quality ratings perceived as somewhat subjective. Students with and without disabilities taught by teachers using the CT Scan made significant gains on vocabulary assessments compared to peers taught by teachers in a business-as-usual condition (Kennedy et al., 2018). COACHED is used as part of teacher candidates' field experiences at teacher preparation programs around the country (e.g., Illinois State University, North Georgia University, University of Virginia).

FLITE: STEM Coaching

The overarching goals of the FLITE: STEM Coaching project are to (a) create a toolkit from existing OSEP OERs for mathematics and science coaches aligned with the HLPs and an analytical observational tool to support coaches working with special education teachers K-8 in STEM content and (b) create a dashboard with objective data output from observations and coaching inclusive of teacher-driven physiological data and resources for coaches to support special education teachers in K-8 STEM content supporting students with mild to moderate disabilities.

The team already has a prototype of the "free" tagging tool aligned with STEM and HLPs called Debriefscape™ (http://ucf.deviws.com) that is ready for use. This tool is web-based (no app to download), and all videos and tags reside with the user, not the research team. The video remaining with those who are tagging avoids any human subject issues or issues with student video, unlike sites that might store video for the user. In addition, the site offers a project-based coaching model to help prepare STEM coaches (or any administrative person observing the teachers) to provide iterative feedback to teachers working in STEM areas. The team also provides a way to tag videos and allows for integrating biometric data if the teacher desires. The purpose of the project is to provide support and identify areas of gaps aligned with the HLPs in STEM, and instead of a coach needing to provide the follow-up PD, the online resources harvested for the site provide support to teachers completing personalized learning of concepts they want to address.

Quadrant 3

Novice teacher candidates might consider technology in this quadrant, but the teacher educator will need more advanced technological skills. An increasing body of evidence suggests that AI, emerging biometric data, and simulated environments, which have a solid research base, can impact teacher education. The tools in this quadrant do not require the same leap of teacher educator and teacher candidate as those in Quadrant 4, but the authors recommend developing these ideas in a course prototype and being open to learning new technology skills before widespread adoption.

Existing Artificial Intelligence

Review of Practice

The potential of AI has yet to be fully exploited in education, but it is an emerging technology. The challenges with AI are the large and expansive underlying engines we only sometimes understand (why Siri confuses what we say), the massive amount of data AI could produce, and how to best use that data. In teacher education, limited use is currently occurring in research (Chiu & Chai, 2020).

Several startups are building customizable, trainable platforms that learn from the user and, in turn, represent the user online via a personal digital copy (i.e., digital clone). The company Replika is a programmable digital twin that can deploy contacts. Another company, Molly, answers questions via text. The near future may include digital twins for professionals across a range of fields in health and education. The issues as these tools emerge are standardizing them for practice and allotting time and funding for the research. However, President Biden announced 2021 funding of $874 million for direct investment in AI. China is forging the lead in data collection, mining data to train AI to detect patterns in everything from education to manufacturing to military applications (Webb, 2022). The purpose of this funding is to help the United States catch up. Therefore, the IC team supports considering this area in teacher preparation.

Underlying Research

Although the research in this area aligns with teacher preparation, it is only at a discussion stage about potential use, roles, and impact. In a qualitative review of teachers' perceptions, some initial theories of how the self-determination of the teacher aligns with the early adoption of AI tools are emerging (Chiu & Chai, 2020). Several categories of using AI were identified in a review of 400 articles on AI and deep learning, but no direct studies were conducted on teacher education. Some of the themes found in the current use of AI included computer-assisted instruction, intelligence tutoring, education games, predictive modeling, adaptive learning, learning analytics, educational agents, and teacher evaluation (Guan et al., 2020). The only other significant review in teacher education at the time of publication reflected the research on the intersection of AI and learning analytics, showing use but a lag in most other disciplines (e.g., medicine, industry, finance; Salas-Pilco et al., 2022)

Usability

The authors of this IC have seen a few cases of AI in the classroom and are working on projects to create AI agents to support students in executive functioning in the general education setting (Hughes et al., 2022). In addition, simple AI applications in the classroom, including Google Home or Alexa, help students with speech or setting timers. One set of classroom teachers has Google Home saying "self-check" every 10 minutes, at which time the students do self-monitoring. Despite the emerging use in teachers' classrooms, how AI will be used in preparing teachers is an area where usability will have to come from innovative adoptions and prototyping of models for other teacher preparation institutions to use. For example, could AI robots coach, and can emerging chatbots become advisors or recruiters to ensure quicker time to graduation or increase recruitment? The usability of emerging AI will certainly happen, but the future of using it will be up to the advanced tech adopters in higher education, who will teach us how AI can provide new ways of thinking and learning for teacher education students.

Emerging Biometric Data

Review of Practice

The authors of this IC could never list all the emerging tools that could impact the ability to coach and support novice or expert teachers in honing their skills related to heart rate, galvanic skin response, eye tracking, and even brain wave measurement tools (e.g., EEG). The plethora of emerging devices reflects the forward movement in many fields of medicine, military training, and even athletics. This team has, to date, reviewed the potential power of the Empatica, Apple Watch, Spire, Polar, Fitbit, Aura, iMotions, and Garmin, to name a few tools that look at basic heart rate, skin temperature, respiration rates, and brain waves. These tools are in Quadrant 3 because, from the authors' experience, using these tools is easy in theory, but in reality, getting real-time data or ensuring the privacy or usability of the data is challenging. The field of teacher education should be looking at emerging tools, such as the AIRA, which supports people who are blind by providing them with a virtual visual guide through a small camera on a pair of glasses that uses GPS tracking and an earpiece so the human AIRA guide can talk to the person and provide feedback. This type of coaching is at a level we have yet to explore, but based on the work of Rock, Gregg, Gable, & Zigmond (2009) and Scheeler and colleagues (2006, 2012), the field already has a firm foundation on how discrete coaching works. How these various tools might elevate from simply watching teachers' outward moves in practice to understanding the neurophysiological state through the teacher's mind and body is still to be determined.

Also, the quote about the eyes being the window to the soul is coming to fruition. The authors of this paper are looking into tools such as Lexplore to track various eye movements for children with and without dyslexia; iMotions to track eye movement in and out of an online environment; and the more expensive and more advanced Tobii2 to track eyes with an EEG cap.

Similar tools are emerging for facial tracking, but if you are using Quadrant 3 technology, understanding that all of these devices have biases (e.g., facial tracking and heart rate have a potential bias based on skin color or age) is critical. Like any technology tool or study, potential bias must be noted and mitigated to the greatest level possible; dismissing a tool if the risk of bias is too great might be the best action.

Currently, the tools most often discussed or used are biometric tools at the lower end of technology and cost. The most common tools to consider are typically basic, cost-effective, and often already teacher-owned tools, such as the Fitbit, Garmin, or Apple Watch, yet the back-end data of these tools are not equipped to easily gather and analyze across teachers. Polar is a new tool currently being explored to allow for easier back-end analytics. Many people are talking about making their biometric data their own to ensure privacy and not be encumbered by proprietary software. No matter the pathway or the tool, the future will allow for more data on teacher movement, eye tracking, heart rate, respiration rate, and brain wave patterns. The question for teacher educators will be for what purpose and how will they gather and use this data. Also, these types of data create a new world of privacy, bias, and the need for advanced statistical and data analytical tools and methods to understand how to use these new tools in teacher and student learning (Hernandez-de-Menendez et al., 2021).

Biometric Data

Review of Practice

Many people today wear or carry devices that track their steps and heart rate and can even remind them to take a break when stressed. The future of biometric data in teacher education is an area the authors see as emerging. At the simplistic level, the FLITE: STEM Coaching team are already attempting to align biometrics with tagging. However, this team of teacher educators and computer scientists have learned that this work is not yet ready for widespread adoption, despite the potential for this tool to help in understanding differences of stress levels in expert versus novice teachers and to potentially help stop the churn of teacher candidates who are leaving the field.

Underlying Research and Emerging Trends

The FLITE: STEM Coaching team is considering using biometrics aligned with tagging tools to support teachers. This type of data could easily be integrated with telehealth, telecounseling, and even daily stress and reflection for teachers to lower stress and increase retention in the field.

This work in basic biometrics (e.g., heart rate and movement data) is commonplace, but other neurophysiological data provided by tools like iMotion to look at eye tracking or Tobii2 to locate eye tracking in movement and EEG waves combined is possible. However, this work needs to happen in collaboration with learning scientists, computer scientists, and psychologists to help us understand the multi-modal data we might receive and what it could mean in our work. Wang (2022) goes as far as proposing a research agenda for using tracking in teacher education.

While the focus is currently on single-session analyses, the Debriefscape™ tool can embed multi-session analyses. For instance, the user can select a teacher and view how that person's performance on one metric changes over time. This type of performance review can occur for all sessions or just selected ones, such as the last two, to determine more immediate changes. The Debriefscape™ software allows coaches to see how their teachers respond to coaching feedback. The current format of this platform is device agnostic, and any CSV file, such as those produced from devices such as the Apple Watch or Fitbit, can be integrated and overlaid on teacher performance in any environment, allowing for a personalized, multi-modal dashboard of information to create more objective coaching models.

Underlying Research

Limited research in education in this area exists, but advocacy and discussions for how teacher-centered biometric data could help teacher candidates see patterns in their data are emerging. Much like people take their temperature when they are sick to determine when to seek medical advice or those who need their blood pressure monitored to collect data, this same type of analytical approach to examining teachers’ behaviors is possible. What the data means and how to use it is not nearly as refined as it is in medicine, but more biometrics could provide nuanced information to teacher education, much like a thermometer. A fever is not always bad unless it gets too high. When does the stress rate in blood pressure or pulse during teaching become too high? How does it differ from teacher to teacher? The future pathway is possible as new and emerging technologies are adopted. In an editorial in the *Journal of Technology and Teacher Education*, Mouza et al. (2022) discuss the potential shift post-pandemic in looking at teacher education practices, such as biometrics, through such lenses (Wang, 2022).

Usability

How might these Quadrant 3 tools be integrated and used in teacher education? The ideas and potential are endless, and they depend on programs with more advanced technology adopters to help the field figure out and realize the potential. A current OSEP Stepping Up grant is one of many examples of the future use of biometric and overlaying multi-modal data streams to better understand and support teacher preparation.

Simulated Environments

Review of Practice

Simulations using technology are tools that make scenarios look and feel like real-life situations, with participants acting like they would in a real-life situation. Teaching simulations emerged as written case studies that pre-service teachers read in class, watched as video vignettes, or role-played with classmates to learn a targeted skill or set of skills. More recently, researchers have been looking at simulated classrooms comprised of student avatars (Cohen et al., 2020; Mikeska & Howell, 2020) while continuing to look at tools such as Sim School for less immersive simulated experiences. Simulations typically incorporate technology in scaffolded levels of immersion in games, avatars, and fully immersive head-mounted-display (HMD) simulated environments. The evolution of these simulations changes as technology evolves. Immersive and technologically supported environments have long been an industry standard for practice in the military, aviation, and medicine, but using and researching simulations in teacher education is also evolving (Clarke, 2013). Few researchers have examined relationships between what is learned in simulation and classroom teaching (Ersozlu et al., 2021), and only a few studies have occurred to date (Cohen et al., 2020; Dieker et al., 2019; Straub et al., 2014). A summary of the current research shows various uses and approaches and promising outcomes for students using simulation in teacher education (Dieker et al., 2023). Using virtual rehearsal in a simulator to impact the performance of science teachers examines the systematic variation of different simulation features regarding effectiveness. In a Delphi study, Donehower and colleagues (2020) determined the best practices in special education to use in simulation. Their work noted that simulated environments could help in learning a skill while studying the participant's behavior in a way that does not put real people at risk (in teacher education, this real person would be the student) and allows the person who is in the simulator (in this case, the pre-service teacher) to practice until a level of mastery or a target is reached. Technological simulations in teacher education can range from playing a low-tech game online to a more immersive environment like Sim School; Second Life (SL); or Active Worlds, where teachers role-play as an avatar (i.e., a simulated person).

Underlying Research

Simulations can provide fully immersive environments, much like a flight simulator, where the teacher interacts in what appears to be a natural environment of students, like TeachLivE™ or Mursion. The environments (a few recent studies using this technology are as follows: Dalinger et al., 2020; Ferguson & Sutphin, 2020; Horn & Rock, 2021; Hudson et al., 2019; Landon-Hayes et al., 2020; Lee et al., 2021; Peterson-Ahmad & Landon-Hayes, 2020) provide a chance for virtual rehearsal (Dieker et al., 2019). For a list of all research to date, see http://teachlive.org and Dieker et al. (2023). Simulated environments allow teachers to practice new skills, providing them with a higher concentration of training tasks in each period than is usually possible in the classroom. The teachers receive an immediate review of their performance in the simulator. If the performance is not at an acceptable level, the teacher, with feedback from the After-Action Review, can go through the simulation again. The targeted skill can be practiced in the simulated environment until the desired level of competence is met. Thus, teachers return to the classroom with the new skills and the confidence to implement them.

Dieker, Hynes, et al. (2014) found that teacher participants in a mixed-reality simulation changed one critical teaching behavior after spending less than four 10-minute sessions. Using a pre-post, quasi-experimental control group design, the effective teaching strategies gained in the simulator were found to transfer into the middle school mathematics teachers' classrooms, and a similar study of transferring skills into a science classroom occurred in 2019 (Dieker et al., 2019).

Usability

Using simulators in teacher education should be embedded into clear course objectives to create muscle memory for pre-service teachers or to retrain the muscles of in-service teachers. Scholars at a convening funded by the National Science Foundation (NSF) on the state of these simulation experiences in STEM, inclusive of special education (Mikeska et al., 2021), found a range of tools being used to impact teacher practice, including card games, standardized patients, online games, and fully immersive simulators. The industry standard for using a simulator is typically following the ARC Cycle (Institute of Defense Analyses, 1999). This cycle includes Before Action Review (i.e., setting the BAR); Action (i.e., time in the simulator is approximately 10 minutes); and After-Action Review (i.e., AAR, known in our field as teacher reflection) with a minimum of four sessions to ensure a targeted skill increases. Bondie et al. (2021), in a systematic review of digital puppeteering in teacher education using simulation, note that the future needs to examine the acquisition of the transfer of skills from simulation to practice and the quality of the skill transferred into practice. The future of these environments, tied with personalized analytics, biometrics, eye tracking, and the ability to incorporate quantified data (Johnson et al., 2014), such as giving coded feedback or measuring heart rate or blood pressure, could provide new opportunities to finetune or even remediate practices of teachers interested in using this type of tool as part of their initial and ongoing development. Yet, using any environment to simulate practice, even if fully technologically driven, was and is created by humans with innate bias and potential bias and stereotypes, and other important characteristics of students created in these environments need to be acknowledged with caution to weigh the positive outcomes and the potential lack of positive educational outcomes (McGarr, 2020).

Quadrant 4

Emerging Technologies

The skills in Quadrant 4 require innovative leaps in use, experiential thinking, and prototyping to ensure that adoption is impactful and cost-effective for the teacher educator and teacher candidates. Think about how in the 1980s, online learning emerged and how in the 2000s, simulation emerged. Some teams still see these tools emerging into the year 2030 and beyond. The tools in this quadrant are currently available, yet their use is still unpredictable in teacher education. If a program team decides to delve into the tools in this quadrant, sharing their findings is critical as the tools here will potentially be mainstream tools of the future. The authors of this IC attempted to look into their crystal balls and could be wrong about their predictions, but the discussion in this quadrant is for teacher educators and their teacher candidates who are ready to go beyond traditional thinking.

Artificial Intelligence

Review of the Practice

As AI technology rapidly evolves, its capabilities will play an increasingly important role in education. Already, AI applications are being used to personalize learning for students and provide teachers with real-time feedback on student progress. In the future, AI could become even more involved in the educational process, serving as a virtual tutor or personalized coach for students of all ages.

Review of Practice

AI systems can analyze large volumes of data quickly and accurately, making them ideal tools for sorting through vast amounts of information to find the most relevant to students' needs. Additionally, machine learning algorithms can adapt over time as they gain experience, becoming better able to anticipate individual students' strengths and weaknesses, allowing AI tutors to provide highly customized instruction individualized by subject, skill level, and specific areas where assistance may be needed. In an article on challenges, opportunities, and implications for teacher education, Whalen and Mouza (2023) summarize the potential use and challenges the field needs to consider.

In addition to assisting with academic subjects, AI technologies could help teach essential life skills, such as interpersonal communication and decision-making (Mosher et al., 2022). Virtual coaches could monitor online interactions between friends or classmates in social networks and offer constructive feedback based on observed behavior patterns (e.g., "It seems like you got into an argument with your friend again; here are some suggestions about how you might handle that situation differently next time"). Similarly, intelligent agents could help individuals plan their lives by providing advice on financial planning or choosing a career path. Seemingly, no area of education will be untouched by AI in the years ahead.

Usability

GPT-3 Open AI's language generator allows individuals to write scenarios. For example, Eleazar Vasquez gave the following instructions to Chat GPT-3 given the following instructions: "Please write a short essay around 850 words. Focus on how AI will evolve for K-12 and higher education. Make it sound like science fiction, but keep it factual." Eleazar used GPT3 to produce several different outputs and selected one scenario as his favorite. GPT-3 took 3.29 seconds to author this essay, and Eleazar decided to do a little editing. This example illustrates how AI is already being used in schools today, and it will likely become more prevalent. Here are three ways AI may continue to transform education:

1. Personalized learning: One-size-fits-all education models are quickly becoming obsolete thanks to advances in personalized learning powered by data analytics and machine-learning algorithms. With these technologies, teachers can tailor instruction to each student's needs, increasing engagement and overall academic performance.
2. Automated grading: As online learning becomes more commonplace, automated grading using natural language processing (NLP) algorithms will also become more common. These systems can provide detailed feedback on essays or written responses much faster than human graders, making them ideal for high-volume assignments, such as massive open online courts (MOOCs).
3. Bots as tutors: In addition to acting as digital assistants, bots are beginning to emerge as skilled tutors capable of holding conversations with learners, providing real-time feedback and adjusting scaffolding based on the learners' progress. Many popular chatbots like Duolingo have already been employed in classrooms.

Extended Reality: Virtual Reality, Mixed Reality, and Augmented Reality

Review of Practice

Using extended reality (XR), which includes virtual reality (VR), mixed reality (MR), and augmented reality (AR), holds great potential for the teacher education field. XR encompasses the continuum of immersion that occurs with evolving and emerging technologies, often referred to as "moving into the metaverse." Will the future be that first-semester field experiences occur in a "meta" classroom? Will areas of deficit in teaching students be remediated in immersive environments like doctors practice virtual surgeries? Or will expert teachers be available to teleport into the classroom to co-teach? XR tools are the foundation of training and preparation in military, aviation, and medicine, but the interconnectivity of these environments and how they will scaffold learning and practice is just emerging in teacher education.

Underlying Research

Despite some levels of simulation emerging from an NSF conference on the state of STEM tools inclusive of special education (Mikeska et al., 2021), the level of simulation use across XR platforms is just emerging. Although the COVID-19 pandemic accelerated online learning, moving to XR is at the cutting edge in teacher preparation and learning. These tools hold great promise for students who struggle with abstract concepts, providing opportunities for immersive scaffolded experiences (Sırakaya & Alsancak Sırakaya, 2022). The richness of these environments is that, unlike current student teaching, these tools and worlds are not left to chance, much like the current model for field experiences or student teaching. Instead, the highest-level experts are attempting to create the utopia of settings for ultimate practice before encountering various real-life problems.

In XR training, the outcome must be 100% successful, as these tools are used in high-stakes and high-risk environments, which is just what we need for students with disabilities, especially following a significant lack of outcomes following the pandemic.

Usability

Like the emerging simulation in teacher education, activities and learnings are also emerging in the more sophisticated XR environments. How the metaverse is evolving is still imagined in most fields and is, at best, at the novice level in teacher education. Authors Dieker and Vasquez favor two technology quick reads from the National Defense Industry Association, which publishes a monthly magazine about the state of military spending and technology. This work often predicts what is in the pipeline for fields (e.g., exoskeletons to help with soldiers carrying heavy equipment, interconnected simulations, standardized XR environments). The potential usability of XR in education is not yet a cost-effective pathway for all programs, but as costs decrease and creating these worlds become commonplace, so do opportunities for use in teacher education.

Machine Learning and Multi-Modal Data

Review of Practice

Using machine learning (ML) and multi-modal data (MMD) creates new pathways for learning and developing AI (see an example of ideas for the future at https://research.aimultiple.com/multimodal-learning/). Search engines, AI agents, and social media use this data to determine which ads to send people or what recipes or other information they might like to receive. This technology-integrated mindset is also commonly used for predictive analysis in medicine, weather, and other fields. ML and MMD are on the horizon for teacher education. The field already uses MMD when looking at passing rates of teachers on state tests and accreditation standards, but how ML might use that data to change the content of courses, eliminate courses, or even create new pathways for learning is yet to be realized. The future use of the metaverse, especially more integrated technologies, could emerge beyond what a group of well-educated teacher educators decide a machine can notice in the patterns of data we might collect from video observation, tagging, and biometrics. What might ML realize from large-scale numbers of teachers in simulators or their work in online games or other environments? Regardless of the program, the more data gathered, the greater the opportunities and potential pitfalls.

Underlying Research

From a search of the literature, ML and MMD in the field of learning sciences are being used to understand students' executive functioning and create ML algorithms from gathering large data sets. How ML and MMD can be harnessed to shape our thinking about teacher performance that aligns with student learning remains to be seen. Ideas such as multi-modal active learning from human data are emerging with what some call a deep reinforcement learning approach (Rudovic et al., 2019). "Human behavior is inherently multi-modal, and individuals use eye gaze, hand gestures, facial expressions, body posture, and tone of voice along with speech to convey engagement and regulate social interactors" (p. 6). Integrating data and identifying whether this work first emerges in student learning or teacher behavior in natural contexts is still unknown.

Usability

The power of predictive analytics to evolve from ML and MMD is exciting, but caution is necessary as the real power in teacher education is blending of humans and machines. Currently, the field relies heavily on professional judgment without all data points. Flipping that scenario, with the field only relying on ML and MMD, most likely will never or is a long way from occurring when looking at the unique nuances in the field of special education in both the teachers prepared and the students served.

Ethics, Privacy, and Safety

Diversity, equity, inclusivity, and belonging are at the core of teacher education; however, our field can help alleviate issues and create unintended new ones. From cyberbullying to biometric and facial tracking data, all of which hold bias, extreme caution and discussion are critical for adopting all technology. All technologies come with bias, privacy, and potential safety issues because of the decisions developers make. Like any article, textbook, case study, or video can misrepresent or violate someone's privacy or make someone feel judged or unsafe in their learning environment, teacher educators must be mindful of the bias inherent in the technology that humans create and use. We must continually evaluate and reevaluate policies surrounding privacy, safety, data security, identity, representation, bullying, and general code of conduct procedures. These statements are simplistic for such a complex issue, but technology can help negate or permeate bias and create known or yet-to-be-learned safety and privacy concerns. As teacher educators consider using the tools in Quadrants 3 and 4, they must engage diverse stakeholders and thinkers to acknowledge, address, and evaluate the issues of using or potentially misusing technology.

Closing Thoughts

Technology does not afford the necessary modality to present visual stimuli nor the interactive capabilities to provide the necessary discriminated feedback on student responses. This level of specificity for preparing teachers depends on the modality of the media and the content presented within the media. Regardless of the technological tool used in teacher education, the research base needs to be considered, shared, and reflected on for cultural relevance, potential bias, and impact on teacher performance and student learning outcomes. For example, a high-end computer conferencing system can afford real-time, two-way audio and video, but does the cost create a more effective way to interact? Video tagging tools can be purchased and used to help identify skill deficits, but does identification lead to remediation and change? The ways technology can enhance or hinder instruction and learning outcomes are often subtle; therefore, new forms of technology to deliver instruction in teacher education need to be empirically validated to make claims of effectiveness.

As technologies continue to emerge, the burden is on members of the teacher education community not to accept the latest and greatest technological tools and apps at face value, instead opting to conduct experimental trials and asking appropriate research questions by engaging with a wide range of stakeholders to ensure evidence of effectiveness and cultural relevance because teacher education aims to prepare future and practicing teachers for success with one main target—teaching students with disabilities.

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Appendix A
Innovation Configuration: Use of Technology in the Preparation of Pre- and In-Service Teachers

Expert to Novice Use: A Grid for Technology Adoption in Teacher Education

	Novice Teacher	Expert Teacher
Novice Tech User	**Quadrant 1** · Case studies (video or text-based) · Podcasts · Online resources · Bug in the ear	**Quadrant 2** · Coaching with tagging software · Virtual coaching
Advanced Tech User	**Quadrant 3** · Existing AI · Emerging biometric data · Simulated environments	**Quadrant 4** · Emerging AI · XR including AR, VR, and MR · Machine learning and multi-modal data

Essential Components	Implementation Levels				
Instructions: Place an X under the appropriate variation implementation score for each course syllabus that meets the criteria level from 0 to 3. Score and rate each item separately.	**Level 0**	**Level 1**	**Level 2**	**Level 3**	**Rating**
	No evidence the component is included in the syllabus, or the syllabus only mentions the component.	Must contain at least one of the following: reading, test, lecture/presentation, discussion, modeling/ demonstration, or quiz.	Must contain at least one item from Level 1, plus at least one of the following: observation, project/activity, case study, or lesson plan study.	Must contain at least one item from Level 1 and at least one item from Level 2, plus at least one of the following: tutoring, small-group student teaching, or whole-group internship.	Rate each item as the number of the highest level receiving an "X."
1.0 Case Studies					
1.1 Anchored in the content. 1.2 Fewer than 30 minutes. 1.3 If using for research, consider trade-off between the number of videos and the potential confounds.					

1.4 Consider three elements: (1) the content, (2) the context, and (3) the multimedia. 1.5 Identify an explicit instructional purpose for the use of the video case study. 1.6 Set explicit instructional objectives for intended learner outcomes. 1.7 Select previously developed video case study developed based on current learning theory. 1.8 Or, if developing video case study, consider learning theory in its development. 1.9 Choose/develop narrative video that is of sufficient duration, complexity, and explicitness to meet the instructional objectives. 1.10 Ensure that video case study instruction is adequately mediated, either by the instructor or through the technology, to focus learner attention on the critical aspects of the case.					

1.11 Employ multiple scenarios or cases as comparisons of parallel cases to enable the development of cognitive flexibility. 1.12 Engage learners in sustained activity around the case. 1.13 Provide iterative feedback on skills performance and transfer attempts, enabling learners to revise their efforts based on feedback.					
2.0 Podcasts					
2.1 Podcasts are incorporated into courses where appropriate and aligned with content. 2.2 Podcasts contain key content likely to be prioritized during lecture, on assignments, on assessments, and for use in practice. 2.3 Podcasts contain rich content that are of any length, cover any topic, and might include any number of instructional approaches. 2.4 Podcasts cover topic of importance in the training program. 2.5 Podcasts include several instructional approaches.					

3.0 Online Courses					
3.1 Ensure that communication between faculty and student is constant and effective; consider use of e-mail, web-based conferencing (webinar), blog postings, online discussions, phone contact, FaceTime, Skype, or Google Hangout. 3.2 Discuss and define course policies, teacher expectations, and plagiarism early in course. 3.3 Provide cooperative learning opportunities to facilitate critical thinking, brainstorming/problem solving, study groups, and using dyads and peer-assessment activities. 3.4 Provide experiential and active learning activities utilizing Bloom's Taxonomy and the Theory of Engagement to activate areas of the brain responsible for higher-order thinking and active learning that address the construction of knowledge through analysis, synthesis, and evaluation.					

3.5 Ensure that structure and content require student to make decisions, conduct experiments, and explore ways to solve real-world problems, case studies, and scenarios that lead to transference of learning in practice. 3.6 Give punctual feedback. 3.7 Structure opportunities for practice and establish peer tutoring when necessary. 3.8 Express high expectations by continually motivating, commending successes, and providing stimulating activities. 3.9 Embrace cultural diversity and different learning styles by incorporating Gardner's Multiple Intelligences. 3.10 Provide differentiated instruction by knowing students and learning how to best impact their learning in this environment.					

3.11 Ensure accommodation of learners needing special assistance and assistive technologies.					
4.0 Bug-in-Ear					
4.1 Consider how to best integrate eCoaching into program. 4.2 Use eCoaching with special education pre-service teachers and general education counterparts during co-teaching planning and instruction. 4.3 Educators should consider extending eCoaching use from early, mid, and late field experiences to include induction support. 4.4 Identify how to use eCoaching in early experience. 4.5 Differentiate how to use eCoaching in mid field experiences. 4.6 Differentiate how to use eCoaching in late field experiences. 4.7 Consider how to use eCoaching in beginning induction to the field. 4.8 Use inexpensive and validated tools for e-coaching.					
5.0 Coaching with Tagging Software					
5.1 Tools are embedded and have clear connections to course objectives.					

5.2 Fully immersive simulators ensure use of ARC cycle. 5.3 A minimum of four 10-minute sessions are used that focus on a targeted skill in teacher practice in an immersive simulator. 5.4 Ways to investigate impact of online simulations are a part of the development as new environments emerge.					
6.0 Virtual Coaching					
6.1 Target of coaching is aligned with high-leverage practices (HLP) and evidence-based practices (EBPs). 6.2 Coach understands best practices in special education. 6.3 A targeted amount of time and focus of coaching is identified and clarified by coach and mentee. 6.4 Targeted skill is tagged and discussed with the mentee. 6.5 Follow-up tools, professional development (PD), or coaching is provided.					
7.0 Existing Artificial Intelligence					
7.1 Investigation of simple tools are identified and integrated into program.					

7.2 Teacher candidates are expected to be open to and ready to adopt emerging tools.					
8.0 Emerging Biometric Data					
8.1 Program provides opportunities for teachers to discuss the potential implications of emerging biometric data in relation to understanding student academic and social emotional learning. 8.2 Teacher candidates explore ideas related to using biometric data to better help them understand their own stress levels in teaching. 8.3 Preparation program considers how to integrate teacher candidate biometric data aligned with observational tagging.					
9.0 Simulated Environments					
9.1 Tools are embedded and have clear connections to course objectives. 9.2 Fully immersive simulators ensure use of ARC cycle. 9.3 A minimum of four 10-minute sessions are used that focus on a targeted skill in teacher practice in an immersive simulator.					

9.4 Ways to investigate impact of online simulations are a part of the development as new environments emerge. 9.5 Transfer of simulation to "real" practice is integrated into design.					
10.0 Examining Future Artificial Intelligence Tools					
10.1 Discussion takes place around evolution and use of future AI tools and support for teacher and student performance. 10.2 Teacher candidates are expected to be open to and ready to adopt emerging tools. 10.3 Clear course content where considerations for personalized learning use, automated grading, and bots as tutors are investigated.					
11.0 Extended Reality					
11.1 Teacher candidates understand the possibility of XR tools in student learning. 11.2 Teacher candidates investigate the opportunity of XR environments to support students in understanding abstract concepts. 11.3 Program incorporates investigation of fields outside of					

education that engage in XR development.					
12.0 Multi-modal data and Machine Learning					
12.1 Program provides opportunities for teachers to discuss the use of multi-modal data in relation to student learning and the foundations evolving from learning sciences. 12.2 Discussions around the use of predictive analytics and identifying student learning needs is embedded in program.					
13.0 Ethics, privacy, and safety					
13.1 Teacher candidates demonstrate competency in protecting students' identity in various technological environments. 13.2 Teacher candidates discuss and identify potential ethics, privacy, and safety.					

Appendix B
Summary of Evidence-Based Practices Use of Technology in the Preparation of Pre- and In-Service Teachers

Evidence-based practices (EBPs) in this innovation configuration (IC) are defined as practices substantiated by individual research studies and ranked as emerging, limited, moderate, or strong based on alignment with https://ceedar.education.ufl.edu/wp-content/uploads/2014/08/Evidence-Based-Practices-guide.pdf rather than the traditional What Works Clearinghouse definition.

Expert to Novice Use: A Grid for Technology Adoption in Teacher Education

Technology	**Practices**	**Level of Evidence**	**Citations**
Quadrant 1			
Case studies		Moderate	Anderson et al., 2002; Barnett, 2006; Brunvand & Fishman, 2006-2007; Daniel, 1996; Dieker et al., 2009; Herbst & Kosko, 2014; Herrington & Oliver, 1999; Kurz & Batarello, 2004; Lambdin et al., 1997; Morin et al., 2021; Nagro et al, 2022; O'Brien et al., 2021; Peng & Fitzgerald, 2006; PT3 Group at Vanderbilt, 2003; Santagata, 2021; Walshe & Driver, 2019
Podcasts		Moderate	Evans, 2008; Kennedy, Deshler, et al., 2013; Kennedy, Driver et al., 2013; Kennedy, Ely, et al., 2012; Kennedy & Thomas, 2012; Kennedy, Thomas, Aronin, et al., 2014; Kennedy, Thomas, Meyer, et al., 2014; Kennedy et al., 2011, 2015

Online courses		Moderate	Basham et al., 2020; Chelkowski et al., 2019; Crutchfield et al., 2015; Dalton & Proctor, 2007; Grawemeyer et al., 2017; Hall et al., 2015; Jimenez-Gomez et al., 2020; Kellems et al., 2020; Kennedy, Aronin, et al., 2014; LaRosa, 2017; Marino et al., 2011; Plump & Meyer et al., 2014; Rappolt-Schlichtmann et al., 2012; Reinitz et al., 2022; Starkey, 2020; Ulum, 2021; Vasquez & Marino, 2020; Wallisch et al., 2019; Watson et al., 2011; Yilmaz, 2016
Bug-In-Ear technology		Moderate	Bowles & Nelson, 1976; Elford et al., 2013; Gallant & Thyer, 1989; Hollett et al., 2017; Horn & Rock, 2022; Kahan, 2002; Nagro et al., 2022; Ottley et al., 2015; Regan & Weiss, 2020; Rock et al., 2014; Scheeler et al., 2010, 2012
Quadrant 2			
Coaching with tagging software		Emerging	Baecher et al., 2018; Horn & Rock, 2022; Kennedy et al., 2018; Ruebe & Gallowy, 2013; Scheeler et al., 2006; Wake et al., 2017
Quadrant 3			
Existing AI		Limited	Chiu & Chai, 2020; Guan et al., 2020; Hughes et al., 2022; Webb, 2022
Emerging biometric data		Limited	Hernandez-de-Menendez et al., 2021; Mouza et al., 2022; Wang, 2022;

Simulated environments		Moderate	Bondie et al., 2021; Cohen et al., 2020; Dalinger et al., 2020; Dieker, Hynes, et al., 2014; Donehower et al., 2020; Ferguson & Sutphin 2020; Horn & Rock, 2021; Howell, 2020; Hudson et al., 2019; Landon-Hays et al., 2020; Lee et al., 2021; McGarr, 2020; Mikeska et al., 2021; Mikeska & Straub, et al., 2014; Peterson-Ahmad & Landon-Hayes, 2020
Quadrant 4			
Examining future AI tools		Emerging	Grassini, 2023; Mohammed et al., 2021; Salas-Piloc et al., 2022
ER		Limited	Mikeska et al., 2021; Sırakaya & Alsancak Sırakaya, 2022
Multi-modal data and machine learning		Emerging	Rudovic et al., 2019
Ethics, privacy, and safety		Emerging	Council of Chief State School Officers, 2013 (InTASC Standards); Mandinach & Jimerson, 2021