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Strategies for Encouraging Effective Technology-Enabled Instructional Practices in K–12 Education

A Thought Piece Drawing on Research and Practice

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Executive Summary

Digital technology, including information technology, is widely available in K–12 classrooms across the United States, and its adoption has been accelerated by the COVID-19 pandemic and by substantial investment in technology for education. At the same time, public schools have not necessarily seen a return on investments in that technology. Why? Research is ongoing and there is no single answer, but early signs point to a variety of factors: the varied quality of technologies, the mismatch between the myriad technological tools available and the ways they are used (or not used), the availability and utilization of quality professional learning opportunities to support effective technology use, varying student needs and circumstances, the availability of supporting resources (e.g., home internet access), and other factors.

This paper is a thought piece that was developed by examining peer-reviewed literature, reports, and examples from the field that relate to "technology-enabled teaching and learning," also called "technology-enabled instruction," an emerging term that encompasses not just whether technology is used in the classroom (technology integration) but also when and how teachers use technology in their instructional practices to improve learning outcomes. (See the appendix for more information on the process that went into developing this paper.) At present, there is an abundance of resources about effective technology integration, on the one hand, and about effective instructional practice, on the other. Understanding the elements and effectiveness of technology-enabled teaching—as described in the research and in reports from the field—offers an opportunity to bridge the gap between technology integration and instructional practice.

What specific benefits can technology-enabled teaching provide, and under what conditions? This thought piece discusses the *instructional* uses of technology and their benefits for teaching and learning. (Technology also offers a host of important potential benefits that relate to noninstructional elements; these are not covered in this thought piece.) Researchers label these instructional benefits in different ways, but they can be grouped roughly into the following categories:

- personalization, differentiation, and customization to address learner needs
- curation, availability, accommodation, and accessibility of vetted educational materials and learning environments
- student engagement, interest, and motivation
- communication, collaboration, and relationship-building
- learning analytics

The research indicates that context matters tremendously for effective technology-enabled instruction—particularly when it comes to identifying barriers to this teaching. The literature categorizes barriers as first and second order. First-order barriers are external to teachers (e.g., limited access to technology, insufficient professional development, poor leadership). Second-order barriers relate to the teacher (e.g., real and perceived knowledge and skills, beliefs about technology-enabled teaching, pedagogical values).

First- and second-order barriers are deeply related. Although there has been a decline in first-order barriers, many remain. And second-order barriers persist. The literature shows that teachers' pedagogical beliefs and values are fluid, malleable, and flexible but can be significant barriers to effective technology-enabled teaching.

Systems leaders can support teachers to change beliefs and improve technology-enabled instruction in the following ways:

- align school or district vision, priorities, and plans with technology-enabled instructional approaches
- articulate the benefits of specific technology-enabled instructional practices in comparison with traditional techniques
- demonstrate how technology-enabled, student-centered teaching has meaningfully improved learning outcomes—and identify instances when it has not
- provide vicarious opportunities for teachers to see and experience the benefits of technology-enabled instruction in context-responsive ways
- support social–cultural spaces that promote effective technology-enabled teaching

Introduction

This paper is a thought piece on the ways in which the emerging concept of "technology-enabled teaching and learning" (also called "technology-enabled instruction") can bridge the gap between instructional practice and technology integration, resulting in unique benefits for students. The paper explores how technology-enabled teaching benefits students, the conditions under which it is best deployed, the barriers to adoption, and the role of systems leaders in supporting teachers in deploying technology-enabled instructional practices. The paper does not argue *for* technology but instead suggests that teachers must be empowered to use technologies in pursuit of particular instructional aims in particular circumstances.

Owing to the rapidity of change in technology and schools' adoption of technology—as well as the profound shifts that came from the COVID-19 pandemic—a variety of sources contributed to the ideas presented in this paper, including both peer-reviewed literature and examples from contemporary practice. (See the appendix for additional background.) This thought piece explores these varied materials to suggest benefits to school communities and students when teachers and systems leaders embrace technology-enabled teaching as a holistic approach that encompasses both effective instructional practices and effective technology-integration strategies. It also highlights the role of systems leaders in supporting technology-enabled teaching.

At the same time as pandemic conditions have accelerated access to technology in K–12 educational contexts, learning outcomes—especially among students from historically underserved communities—have not kept pace.

Using technology for instructional practice is not a new phenomenon. Teachers have been using technology in the classroom for decades, whether it has involved word processing applications, typing programs, or presentation software. Although the word "technology" can have a wide variety of meanings, this thought piece uses the term more narrowly to refer specifically to "digital technology," a category that includes information technology.

Although technology has existed for many years, more recently, the pace of technological innovation, the accessibility of technology, a rapidly evolving research base, and global conditions have shifted the conversation about technology in education. Researchers are no longer asking what technologies to deploy in the classroom. Instead, recent research focuses on a more complicated question that puts the educator and the student at the center: How can educators leverage technology to advance instructional practices that promote better learning outcomes? And crucially, what strategies can district and school leaders use to support teachers in using these technology-enabled instructional practices effectively?

The fallout from the COVID-19 pandemic—including so-called "learning loss," declining mental health among students, teacher shortages, low teacher morale, and other challenges

within the teaching profession—adds further urgency to these research questions (Dorn et al., 2021; Jones et al., 2022; Natanson, 2022; Kurtz et al., 2020; Neuman, 2022). During the COVID-19 pandemic, schools and districts across the country invested in technologies, including one-to-one devices, home internet, curricular tools, learning management systems, and videoconferencing platforms for remote learning (Klein, 2021). Aided by an infusion of federal funding and the need for new technologies to support remote learning, spending on technology by school systems increased dramatically, with estimates ranging from $26 billion to $41 billion per year prior to the pandemic to possibly more than $50 billion per year during the pandemic (EdTech Evidence Exchange, 2021). The use of digital technologies by educators also soared, with one report finding that districts used around 1,500 different digital tools per month during the 2020/21 school year, on average (*THE Journal*, 2021).

Yet, at the same time as pandemic conditions have accelerated access to technology in K–12 educational contexts, learning outcomes—especially among students from historically underserved communities—have not kept pace. Indeed, schoolchildren across the country have suffered significant declines in math and reading scores during this period of increased access to technology (Mervosh, 2022).

Technology does not provide benefits unless it is designed well and is used with clear and impactful instructional intention. Teachers who embrace instructional practices that leverage technologies for advancing desired educational outcomes can unlock that potential.

What accounts for this discrepancy? Research is ongoing and there is no single answer, but early signs point to the varied quality of technologies and a mismatch between the myriad technological tools available and the ways that they are used—or not used. As the authors of a 2020 Brookings report on using educational technology to improve learning outcomes put it, "just because technology *can* do something, it does not mean it *should*" (Ganimian et al., 2020, p. 12).

Drawing on Cohen and Ball's (1999) model for improving learning outcomes, the authors of the Brookings report argue that more important than the technology itself is the way that educators, learners, and families interact with that technology (Cohen & Ball, 1999; Ganimian et al., 2020). Instruction is core to all relationships with content, educators, learners, and parents. Technology does not fundamentally change the importance of these relationships as much as it can help improve them.

In other words, technology does not provide benefits unless it is designed well and is used with clear and impactful instructional intention. Teachers who embrace instructional practices that leverage technologies for advancing desired educational outcomes can unlock that potential. For example, consider a well-designed adaptive learning system that generates math questions based on each individual student's performance on prior questions. A student is struggling with adding fractions but does not take the time to read the explanations that follow each incorrect answer or does not watch the system's instructional video on

that topic (P. Moyle, personal communication, December 2022). Though well-designed, the technology is worth very little for this individual student who continues to answer questions incorrectly. While content and the learner are present, missing is a key node in the instructional core: educators.

Given the importance of educators, the variety of technological tools available, the range of quality represented across these tools, and the wide variety of implementation scenarios, it is impossible to identify discrete benefits of technology in education overall. However, the literature addresses five areas in which technology is most adaptable for impact in instruction:

- personalization, differentiation, and customization to address learner needs
- curation, availability, accommodation, and accessibility of vetted educational materials and learning environments
- student engagement, interest, and motivation
- communication, collaboration, and relationship-building
- learning analytics

Researchers increasingly identify the teacher's instructional practices as key to understanding the benefits or deficits of technology in the classroom.

These areas of instruction are uniquely benefited by technology when the technology is of high quality and when educators employ the technology effectively. In other words, technology can provide a kind of "power boost" in these five areas.

In addition, the literature identifies a host of potential benefits of technology that are not necessarily directly about instructional practice but are still important for teachers to consider as they identify teaching and learning practices that make the most effective uses of particular technologies. For example, a learning management system may offer greater efficiency for managing students' grades than a nontechnological approach; or an online form may provide a quicker way of gathering student preferences for a new seating chart than collecting written responses from students would. Technology may also offer advantages as a communication tool between educators and families (P. Moyle, personal communication, December 2022). In other cases, the use of technology may be less effective than approaches that do not require technology.

As this paper will show, researchers increasingly identify the teacher's instructional practices as key to understanding the benefits or deficits of technology in the classroom. This perspective is reflected in the terms that scholars employ to describe the use of technology in education. In the past decade, the terminology has progressed from "technology integration"—which refers to the simple inclusion of technology in the classroom—to "technology-enabled teaching" or "technology-enabled instruction"—which refers to the use of technology to improve instruction. Yet the frameworks that are available for teachers do not reflect this progression; many focus

on technology integration processes and others focus on instructional practices. As later sections of this paper explore further, educator-focused resources do not yet typically reflect the integration of those two: technology-enabled teaching.

The shift to technology-enabled teaching is reflected in the literature's more recent emphasis on understanding how teachers use technology to achieve particular aims under particular conditions. With this emphasis, the literature recognizes the importance of *context* in defining technology-enabled teaching best practices and examines how to leverage technology for achieving a larger instructional goal or desired learning outcome, not as an end in itself. The literature also examines the role of systems leaders in supporting teachers' adoption of effective practices in technology-enabled teaching.

This thought piece examines peer-reviewed literature, reports, and descriptions of examples from the field that relate to research on technology-enabled teaching to

- define technology-enabled teaching and explain how this concept fits into the larger context of research on the learning sciences, instructional practice, and educational technology;
- explore key elements and benefits of effective technology-enabled teaching;
- explore barriers to effective technology-enabled teaching and how those barriers have shifted over time;
- examine the importance of teachers' pedagogical beliefs in technology-enabled instructional practice; and
- delve into how school and district leaders can encourage and support teachers in using impactful technology-enabled instructional practices.

Defining Technology-Enabled Teaching and Learning

In 2013, the educational researchers Peggy A. Ertmer and Anne Ottenbreit-Leftwich issued a "call for a shift in focus from *technology integration* (and the tools used to achieve it) to *technology-enabled learning* (and the pedagogy used to support it)" (Ertmer & Ottenbreit-Leftwich, 2013, p. 175). This was not a simple recommendation for rebranding, but a charge to the field to more explicitly address the relationship between technology and instructional practice rather than merely tallying instances in which technology had been adopted.

In calling for a new focus on "technology-enabled learning," Ertmer and Ottenbreit-Leftwich built on David Jonassen's landmark work *Computers in the Classroom* (1996). In that book, Jonassen argues that students can learn *about* technology, *from* technology, or *with* technology. The last category offers a means for drawing on the unique value proposition offered by

technology instead of attempting to replicate existing classroom practices (as in the "learning from technology" formulation). For Jonassen, the ability to learn with technology has less to do with the tool and more to do with how that tool is used—in other words, the instructional practices that enable the learning to occur.

Ertmer and Ottenbreit-Leftwich argue that this shift in terminology has powerful implications for the type of research that is conducted about educational technology. The still emerging term "technology-enabled learning" signals the need to marry two distinct areas of study: research on the use of technological tools in education, and research on pedagogy and instructional practice.

A similar term, "technology-enhanced learning," aims to bridge these areas of research as well. However, that term suggests a value judgment—that learning is made *better* through the use of technology—rather than describing the process of using technology effectively in instructional practice. As the scholars Adrian Kirkwood and Linda Price explain in the *Technology-Enabled Learning Implementation Handbook* (2016), technology-enhanced learning "suggests that technology can enhance learning in some way, but it is unusual to find explicit statements about what this 'enhancement' actually involves and how learners benefit" (p. 2). For this reason, this thought piece focuses on the concept of "technology-enabled teaching and learning."

With that framing, this thought piece addresses technology both in education and in instructional practice. This marriage is particularly important because technologies available in schools have changed considerably over time and now offer much greater potential for realizing Jonassen's vision. At the same time, teachers' pedagogical aims—with improving learning outcomes chief among them—have largely not changed. What is different is the ability of technology, when applied in particular ways in particular contexts, to help teachers achieve those aims.

Instructional frameworks and technology integration frameworks may each allow educators to get close to technology-enabled instruction, but neither of these types of frameworks alone helps educators reach the space where technology is most adaptable for impacting instruction.

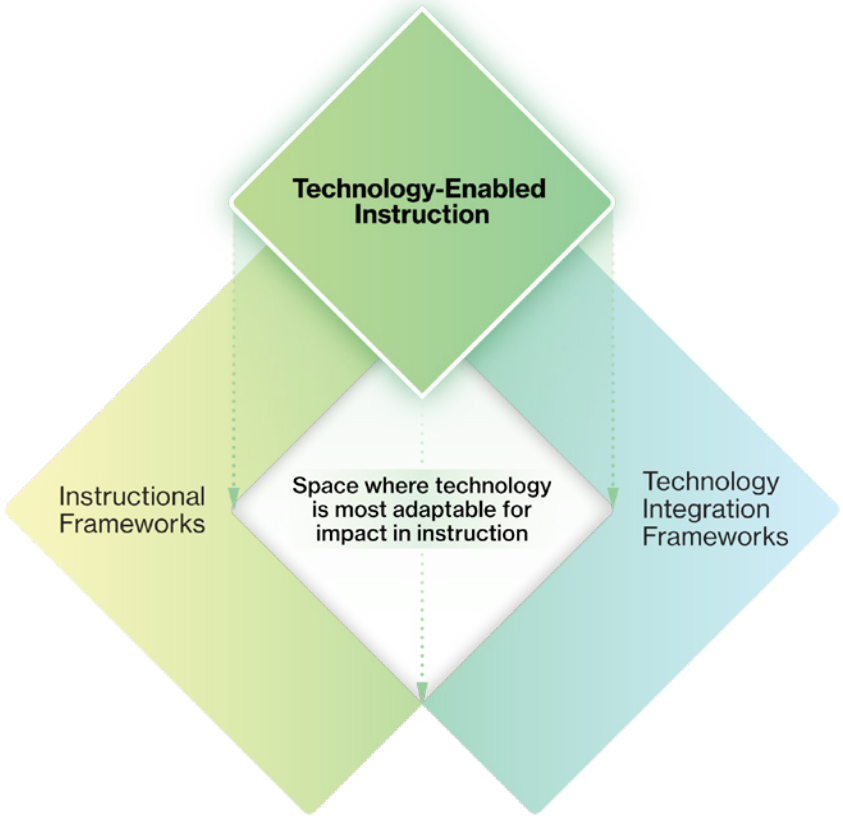
In other words, how can teaching be improved by using technology to advance student learning? As Kirkwood and Price (2016) explain, this approach raises the distinction between "doing things better," through greater efficiencies and other process-oriented benefits, and "doing better things," through transformational teaching and learning practices that derive additional benefits from the use of technology. Both are useful, but they serve different purposes and require different resources. While "doing things better" with technologies can improve student learning, it does not seek to change the "nature of the learning." Kirkwood and Price cite the example of massive open online courses (MOOCs), which make courses more widely accessible but typically rely on lecture formats. In contrast, a teacher

who develops a technology-enabled learning activity that helps students reflect on their own practice is trying to "do better things" (Kirkwood & Price, 2016, p. 35). Both types of improvements are important, and both require better alignment between instructional practice and technology integration.

The need for better alignment between instructional practice and technology integration is also reflected in educator-facing frameworks and materials. As shown in Figure 1, there are many frameworks that aid educators in the use of technology *or* that provide instructional guidance. A variety of conditions and school or district attributes support the use of these frameworks, including the culture of the system, the vision and strategic plan of the district, and other factors. Yet even with support from a school or district, there is a noticeable gap in the area of overlap between the two sets of frameworks. Instructional frameworks and technology integration frameworks may each allow educators to get close to technology-enabled instruction, but neither of these types of frameworks alone helps educators reach the space where technology is most adaptable for impacting instruction.

How can the gap between these two types of frameworks be filled? To answer that question, first consider how technology integration and instructional frameworks typically work.

Figure 1. The Current Frameworks Ecosystem



As an example, the Substitution, Augmentation, Modification, Redefinition (SAMR) model focuses on technology integration approaches and processes (Terada, 2020). In other words, it offers insight into *how* teachers can use technology in specific instances of task design in the classroom. A teacher may find a digital whiteboard to be a valuable tool in the classroom, for example. Using the SAMR framework, the teacher may understand that they are currently using the digital whiteboard as a substitute for a physical whiteboard—the "S" in SAMR. The model encourages the teacher to find ways to use the digital whiteboard to augment (the "A" in SAMR) or modify (the "M" in SAMR) the task of brainstorming, for example. The teacher may ask students to contribute ideas to the digital whiteboard and then make copies of the digital whiteboard for use in small groups. In those groups, students might be asked to sort responses according to a set of criteria and to make reasoned recommendations about which responses have the most merit. These are instances in which the SAMR framework is helping teachers classify their use of technology and push the potential of a tool. But the framework does not help them frame instructional goals or align the goals to specific technologies.

On the other side of Figure 1, a variety of teaching frameworks focus on instruction independently of technology integration. For example, the Danielson framework identifies four areas of teacher responsibility and maps associated practices to each of these domains (The Danielson Group, n.d.). A teacher might identify the importance of communicating the goals and objectives of a learning activity as expressed in Domain 3 of the Danielson framework (Learning Experiences). That teacher may then decide to write talking points that frame what the next lesson is about and why the skill or knowledge the lesson contains is important to students. In this way, the teacher can communicate these aspects prior to the lesson, use the verbiage authentically during the lesson, and ask students to describe the ways they achieved the lesson goals at the end, supporting students' metacognition. But the Danielson framework would not help the teacher to understand whether and how to use technology to advance these aspects of the lesson.

Technology can provide benefits in helping enable better learning outcomes as part of effective technology-enabled instructional practices.

The gap between technology integration frameworks (such as SAMR) and teaching frameworks (such as Danielson) is understandable. After all, technology-enabled teaching can span a wide spectrum of pedagogical beliefs and values and can involve a range of technologies. In addition, technology can be used to pursue a range of instructional goals.

As subsequent sections of this paper explore further, the literature continually indicates that context matters tremendously for technology-enabled teaching to take place effectively. The resulting complexities have contributed to the gap between teaching frameworks and technology integration frameworks. Understanding the elements and benefits of technology-enabled teaching—as described in the literature—offers an opportunity for better linking the benefits of the two kinds of frameworks.

Elements and Benefits of Effective Technology-Enabled Teaching

Technology is ubiquitous in K–12 classrooms. However, as a 2015 literature review explains, "the practical use of this investment has not been impressive" (Delgado et al., 2015, p. 408). The authors of this study conclude that teachers were still using technology primarily for administrative practices such as word processing or managing student records. When teachers did use technology in teaching, they often did so to assist students with practicing lower level cognitive skills such as fact memorization or repetition of a previously learned skill. While these functions can create greater efficiencies, they do not fundamentally shift the nature of teaching and learning.

In other words, instruction itself is not radically transformed for the better by such uses of technology. Nor is merely *having* technology sufficient. Instead, technology can provide benefits in helping enable better learning outcomes as part of *effective technology-enabled instructional practices*.

What specific benefits can technology-enabled teaching provide, and under what conditions?

The current literature offers a set of instruction-focused benefits of educational technology. These are from studies about how students learn best (e.g., multiple modalities for expression, real-world scenarios) and efficacy studies of particular technologies under particular conditions.

Two areas of this research literature are related to each other but do not relate directly to instruction. First, there is an emerging consensus about the skills and mindsets that are best acquired and nurtured through K–12 education, such as the "4 Cs"—critical thinking, creativity, collaboration, and communication—and social–emotional skills (e.g., National Commission on Social, Emotional, & Academic Development, 2019). Second, the literature identifies a host of important potential benefits of technology that relate to noninstructional elements, including improved efficiency in grade keeping and in communication with families (e.g., Kirkwood & Price, 2016; Office of Educational Technology, 2017).

This thought piece discusses the *instructional* uses of technology and their benefits for teaching and learning. Researchers label these instructional benefits in different ways, but the benefits can be grouped roughly into the following five categories:

- personalization, differentiation, and customization to address learner needs
- curation, availability, accommodation, and accessibility of vetted educational materials and learning environments
- student engagement, interest, and motivation
- communication, collaboration, and relationship-building
- learning analytics

Personalization, differentiation, and customization to address learner needs

At its best, educational technology can provide a mechanism for teachers to personalize and customize their curricula and instructional approaches. The concept of personalization in education predates the modern advent of educational technology and refers to instructional practices that need not involve technology. But technology can help teachers to reach all learners by allowing more effective and efficient methods for customizing instruction and content to support learner variability and the whole child.

In particular, researchers at Digital Promise have identified three areas of possibility for personalization that are aligned with desired student outcomes rooted in the learning sciences and educational policy arenas: focus on growth and improvement, multiple and incremental measures of learning assessment, and opportunities to build greater teacher capacity (Pape & Vander Ark, 2018).

In a study examining teacher attitudes toward pedagogy and the use of technology, Tondeur and colleagues identify the related student-centered concepts of "scaffolds for self-regulated learners" and "accommodating individual learning" as advantages of educational technology when compared with nontechnological approaches (Tondeur et al., 2016, p. 561). Similarly, in the context of assessment, the *2017 National Education Technology Plan Update* from the U.S. Department of Education's Office of Educational Technology (2017, pp. 60–61) explains the benefits of personalization through technology's ability to "provide real-time feedback" and to "adapt to learner ability and knowledge." The theory of assessment for learning—typically contrasted with assessment *of* learning—hinges on the impact on learning of feedback and metacognition (Cambridge International Education Teaching and Learning Team, n.d.). Research specifically on technology-enabled assessment *for* learning as a way of realizing the impact of these benefits is thinner than research on assessment *of* learning.

How does this personalization look in practice? To take one example, personalization may involve providing individualized questions and feedback as part of adaptive, dynamic curricular systems, ideally to ensure that students are provided with material that corresponds to their levels and particular needs. A teacher *could* carry out this kind of personalization with nontechnological tools—assessing students, grouping them according to level, and providing customized materials for the students of each group. However, teachers could save time by delegating these functions to technology.

Similarly, different technologies can provide students with opportunities to learn in a variety of modalities. Students might have the option to view a video (visual modality), engage in a 3D printing project (tactile modality), write an answer to a question, or speak a response to a prompt. Particular learner needs (e.g., a hearing-impaired student's need for nonauditory cues) or instructional goals (e.g., fluency in speaking a foreign language) may dictate the set of modalities that will be most effective.

Both of these examples—an adaptive curricular tool and technologies allowing different modalities for learning—are cases in which technological tools may not only provide greater efficiencies and time savings but also offer greater precision in diagnosing students' particular challenges. If the tools are well designed, they can generate tasks and explanations that respond to those particular challenges and generate data that provide insight into each student's individual learning needs. These capacities, in turn, can allow teachers to mount appropriate interventions, enable opportunities for flexible groupings, suggest different ways that teachers can design lessons, and recommend pacing and pathways for future learning. In other words, the ways in which *teachers* use technology as part of their *instructional practice* are important for evaluating the effectiveness of technological tools.

For example, an adaptive curricular system is worth little if a student is trapped in an endless cycle of making the same mistake over and over again. Instead, according to Michael Horn, the teacher can use the data generated by the system to create a continuously updated personalized learning plan and a strategy for instruction that responds to the needs of each individual learner (quoted in Pape & Vander Ark, 2018, p. 14).

Researchers such as Todd Rose (2016) argue that personalization cannot rely solely on technology-generated data but also must take into account the individual context of each child, including factors such as the language spoken at home, the risk of confirming stereotypes in behavior, learning differences, or a student's level of anxiety, among others. Together, this set of factors is referred to as "learner variability" (Pape, 2018). It is increasingly understood as a construct that applies to all learners, not simply to a subset of those with learning differences. A growing body of literature from diverse fields supports this notion that the complex interweaving of contextual factors impacts learning for all learners—a concept sometimes called "intersectionality" (Bešić, 2020; Proctor et al., 2017). Personalization, differentiation, and customization are ways that educators can respond to this intersectionality intentionally and appropriately.

In other words, personalization is a technique that educators can use to reach *all* learners in more equitable and targeted ways. Technology can aid in that process.

Curation, availability, accommodation, and accessibility of vetted educational materials and learning environments

Accessibility and accommodation are deeply related to personalization and the concepts of learner variability and intersectionality that underlie it. In the literature, "accessibility" often refers to narrow educational technology design features that are responsive to particular learning differences or that comply with particular regulations around serving students with disabilities—features that fit under the heading of "accommodation." For example, websites must provide alternative text to describe images so that students who are visually impaired will be able to access the same content as other classmates. Similarly, instructional videos must include captions to support hearing-impaired students. The benefit of technology in such cases is clear.

"Accessibility" may also refer to a larger set of principles about how to reach students of diverse backgrounds and with different needs, as described within the context of intersectionality and learner variability. The Universal Design for Learning (UDL) framework draws on learning research to describe such approaches and practices (CAST, 2018). These approaches might involve personalization, but they encompass other practices as well.

For example, a teacher might supply students with background knowledge about Latin roots prior to introducing a vocabulary lesson. This framing corresponds to UDL's "comprehension" element within the "representation" section. Technology is not essential for advancing such UDL principles, but it can be useful. For example, technology offers greater efficiencies in customizing the display of information or varying the methods for response and navigation.

A third dimension of accessibility involves making a wide array of educational materials and curation possibilities available to teachers and students. This availability serves learner variability and supports principles, such as "relevance," that UDL cites as important for reaching learners.

Technology can be beneficial in advancing many of these dimensions of accessibility. For example, a social studies teacher can draw on free open educational resources (OER) to curate primary source materials about a historical event, providing perspectives and voices that are not represented in a single textbook. As a result, students are better positioned to achieve the learning objective of evaluating the credibility of historical sources. In another example, students can use technology to participate in a virtual field trip to a manufacturing facility or to conduct video interviews with economists and other experts to fulfill a learning objective related to international trade of goods and services.

As with personalization, these approaches to curation, accommodation, and accessibility of educational materials and learning environments must be deployed under particular conditions in order to be impactful. For example, OER collections are worth very little if the materials are not of high quality, a caution that the United Nations Educational, Scientific, and Cultural Organization (UNESCO; 2018) makes explicit. In another example, a virtual field trip that is not clearly tied to a curricular goal may not advance learning. As explored further in a later section, support and learning opportunities for teachers are essential. Teachers must not be overwhelmed by technology tools. And students must have the digital literacy skills to be able to engage with educational technologies whose design leverages UDL principles.

Student engagement, interest, and motivation

Focusing on personalization, accessibility, accommodation, and curation can also help facilitate student engagement, interest, and motivation. Although engagement, interest, and motivation do not produce positive learning outcomes in and of themselves, research shows that when students are interested in a topic, they are more likely to perform well academically in that area (Harackiewicz et al., 2016). Teachers can encourage

engagement through a variety of instructional practices, including multiple modes of delivery, opportunities for students to have a voice and choice, gamification, and opportunities for students to reflect on their own learning.

When constructed in effective ways and used effectively in instructional practice, technology can have the benefit of facilitating student engagement. For example, it would be nearly impossible for a teacher to create a set of passages that responded to each individual student's particular interests. An edtech program, however, could allow students who are studying reading and writing to select reading passages related to a particular topic area from an extensive list of possibilities. Similarly, when guided by skilled educators, students can use particular databases or the internet to conduct research using sources that would not be available to them without technology. Such processes can foster engagement and cognitive functioning that leads to improved academic performance (Ainley, 2006).

Technology use does not automatically result in greater student engagement. For example, a student who is provided no guidance when tasked with conducting internet research for a school project is unlikely to develop the types of skills and mindsets that are correlated with positive learning outcomes. As later sections of this paper explore further, student engagement in the service of learning hinges on effective instructional practice.

Communication, collaboration, and relationship-building

Technological solutions can also offer teachers opportunities to facilitate communication, collaboration, and relationship-building in classroom instruction. For example, a teacher may ask a group of students to comment on a student's draft of an essay. For this task, technological tools can allow students to respond to comments and suggestions as they are added to the draft, building on one another's ideas in real time. This technology-enabled instructional approach allows for greater efficiency and responsiveness than would otherwise be possible.

Many teaching and technology integration frameworks emphasize these categories of communication, collaboration, and relationship-building. For example, the North Carolina Digital Learning Plan calls on educators to "demonstrate global awareness through engaging with other cultures via advanced communication and collaboration tools" (Friday Institute for Educational Innovation, 2018, p. 15). Elsewhere, the plan identifies the importance of two-way communication tools for various interest holders. Such plans often align communication and collaboration with elements of a student-centered classroom, a pedagogical orientation that is explored later in this thought piece.

Advocates for "21st century skills" argue the importance of schools helping students develop communication and collaboration skills as preparation for future careers—a trend that also can be seen in statewide academic standards, including Colorado's (Carnevale, 2013; Colorado Department of Education, 2013). Employers continually stress the importance of collaboration and communication skills for employees (Moore, 2016).

There is less research about the short-term impact of technology-enabled instructional practices that promote collaboration and communication learning. For example, a 2019 evidence review cites several studies that showed no discernible benefit in learning outcomes for students who used edtech tools in collaborative ways when compared with students who did not work collaboratively and used technological tools (Lewin et al., 2019). Clearly, more longitudinal research is needed to understand whether and how learning communication and collaboration skills in school affects employment and whether there are short-term benefits from an instructional approach that emphasizes these skills.

The research on the benefits of relationship-building is much clearer. Like collaboration and communication, however, relationship-building has benefits that are generally realized in the long term, not within the context of a single term or academic year. Research shows that strong teacher–student relationships are correlated with better learning outcomes in the long term (Roehlkepartain et al., 2017). Additionally, supportive peer-to-peer relationships among students are correlated with higher levels of learning engagement over time (Shao & Kang, 2022). There is also increasing evidence that a network of relationships of varying strengths—as opposed to a single, strong relationship—is important for both short-term and long-term academic gains (Freeland Fisher, 2018).

What role can technology-enabled instruction play in facilitating such relationships? Certainly there are plenty of possible approaches. For example, a teacher might employ an online tutoring program that provides mentoring alongside academic help. Or a teacher might use technology to facilitate conversations with students in other locations, advancing students' global awareness while building relationships. In another example, a teacher might lead a conversation about digital citizenship in technology-enabled lessons, offering an opportunity to build relationships between students and with teachers. What are the positive learning outcomes that can be realized through such approaches? What are the long-term benefits of such instructional practices? These are still open questions, and more research is needed.

There are also important ways that technology can help facilitate communication, collaboration, and relationship-building between other groups within the school ecosystem. For example, technology may allow for better communication between school leaders, educators, and families. Or technology may help facilitate relationships between peer educators. While important, these interactions are not instructional and so are not a focus of this thought piece.

Learning analytics

The possibility of data generation and data analysis for learning underlies many benefits of using technology for instructional purposes. As Johnson and colleagues (2010) explain, the data that are interpreted can come from both technological and nontechnological sources. A teacher might examine how many assignments a student completed or the number of times that a student responded to questions in class. It is easy to see, though,

that technology would be useful in collecting and displaying such information. According to Johnson and colleagues, "learning analytics refers to the interpretation of a wide range of data produced by and gathered on behalf of students in order to assess academic progress, predict future performance, and spot potential issues" (quoted in Bienkowski et al., 2012, p. 13). This process can yield a host of noninstructional benefits, including encouraging better school attendance and nurturing better relationships with families. However, this thought piece focuses on the benefits of employing learning analytics to improve instruction.

For example, an adaptive curricular tool for math may show that a student is struggling with decomposition of numbers. A teacher can use the data generated by the tool to tailor instruction to that particular learner's needs. Or a report generated by a curricular tool may provide the basis for a teacher to create leveled groups for small-group rotations in math. In yet another example, a teacher may discover that a student skips over all questions requiring written responses. The teacher may decide to offer the student the option of recording spoken responses instead (P. Moyle, personal communication, December 2022). In other words, technology provides a unique ability to generate data that can benefit teachers' instructional practice and positively impact students' learning outcomes.

Of course, technology's ability to deliver on this promise requires that the data generated by a program are both useful and provided in a timely manner that positions the educators to take action. For example, a teacher might receive information about the total number of minutes that a student participated in using an adaptive learning system without accompanying information about whether the student was participating in active learning or whether the student improved in the percentage of questions answered correctly. It is hard to extrapolate from the one data point alone to generate a responsive instructional practice. Or a teacher may not understand the significance of the data generated in a dashboard. In such a case, a teacher may make the wrong determination about how a student is performing (P. Moyle, personal communication, December 2022). As discussed further in this thought piece, there are numerous strategies that systems leaders can adopt to encourage teachers' effective use of data generated by edtech tools and to select tools that generate such data in the first place. Using these strategies requires first identifying the barriers to effective technology-enabled teaching.

Barriers to Effective Technology-Enabled Teaching

An underlying theme in the literature addressing barriers to effective technology-enabled teaching is that merely having access to technology is not enough to propel effective technology-enabled teaching. In 1999, Ertmer and colleagues identified two categories of barriers: first- and second-order barriers (Ertmer et al., 1999). Over time, Ertmer and other scholars have built on this conception (see Table 1).

Table 1. First- and Second-Order Barriers to Effective Technology-Enabled Teaching

Examples of first-order (external) barriers	Examples of second-order (internal) barriers
Lack of access to technology	Real and perceived knowledge and skills of teachers
Lack of professional development	Teacher beliefs about technology-enabled teaching and learning
Lack of a school or district vision for technology integration	Teacher pedagogical values and beliefs
Poor or unsupportive leadership	

Some researchers have concluded that second-order barriers are a more hardened obstacle to effective technology integration than are first-order barriers (Ertmer, 1999; Ertmer et al., 1999; Newhouse, 2001; Zhao et al., 2002). In other words, merely supplying classrooms with technology is insufficient for encouraging technology-enabled teaching. Instead, teacher attitudes, beliefs, knowledge, and skills are key.

In a landmark work, Hew and Brush (2007) describe a more complex relationship between the barriers. They identify 123 distinct barriers discussed in the literature and categorize these barriers into six groups: resources, institution, subject culture, teachers' attitudes and beliefs, teachers' knowledge and skills, and assessment.

School leaders need to understand their particular context and respond accordingly.

Hew and Brush (2007) argue that barriers cannot be addressed independently of one another. For example, according to Hew and Brush's model, a teacher's attitudes and beliefs that are supportive of technology integration will not have much value unless the leadership of the teacher's institution makes resources available and supports teacher professional development and skills acquisition that, in turn, influence the effectiveness of technology integration. In short, "second- and first-order barriers are so inextricably linked together that it is very difficult to address them separately" (Hew & Brush, 2007, p. 241).

School leaders need to understand their particular context and respond accordingly. One set of barriers may be prevalent in the literature, but other barriers may be more prevalent in a particular school community. While teachers at one school may have strong technology skills, for example, teachers at another school may lack those skills. In some cases, time may prove a more important obstacle than leadership. Whatever the context, understanding barriers and their interdependence is a crucial first step toward addressing them.

The context is also shaped by changes in access to technology. While digital divides remain—particularly when it comes to at-home internet—the switch to remote learning during the COVID-19 pandemic has only accelerated a trend toward greater access to computers, software, and other technologies in schools, decreasing the significance of a first-order barrier.

Teachers' Pedagogical Beliefs and Technology-Enabled Teaching

Teachers' beliefs—the underlying ideas and assumptions that teachers hold—influence the attitudes that teachers have toward using technology (Ertmer, 2005; Windschitl & Sahl, 2002). Hew and Brush (2007) synthesized studies showing that when teachers had a negative attitude toward using technology—that is, they disliked technology—they were less likely to effectively integrate it into their practice, let alone use technology to enable deep learning. That observation held true even when teachers had access to adequate technological tools. As an example, an Australian school had many computers available for teachers to use. However, researchers found that a majority of teachers chose not to use those computers in their instruction because they did not believe that computers could be useful for advancing teaching and learning outcomes (Newhouse, 2001).

Importantly, researchers have found that teacher beliefs need not be about technology per se in order to impact technology-enabled instructional practice. Instead, there is a deep relationship between teachers' *pedagogical* beliefs more generally—that is, beliefs about teaching and learning—and their technology-enabled practices.

What is the nature of those more general beliefs about teaching and learning? Researchers have typically distinguished between teacher-centered beliefs—which are associated with behaviorism—and student-centered beliefs—which are associated with constructivism (Deng et al., 2014). In a student-centered classroom, activity revolves around student needs and relies on student participation for learning. In a teacher-centered classroom, the teacher is the main source of authority, and learning proceeds according to a set and generally inflexible structure. See Table 2 for examples of these two approaches.

Table 2. Examples of Classroom Approaches

Examples of approaches associated with student-centered classrooms	Examples of approaches associated with teacher-centered classrooms
• Inquiry-based learning • Use of simulations • Scaffolding of concepts • Access to information and materials outside of the curriculum • Ability to choose different modalities for learning and expression • Collaborative and group activities alongside independent work	• Lecture-based instruction • Lack of personalization and customization for different learning needs • Students relying on teacher for information and materials • Independent work without opportunities for collaboration • Assignments that focus on correct and incorrect answers

In the context of technology integration, Means and Olson define student-centered pedagogical practices as those that use technology to "promote student learning through collaborative involvement in authentic, challenging, multidisciplinary tasks by providing realistic complex environments for student inquiry, furnishing information and tools to support investigation, and linking classrooms for joint investigations" (Means & Olson, 1997, pp. 17–18). In other words, student-centered technology integration involves the use of technology to enable students to perform higher order tasks, advancing many of the benefits of technology described earlier in this thought piece.

Student-centered beliefs correlate with technology-enabled teaching, but teachers' general pedagogical beliefs and their beliefs about technology-enabled teaching and learning can also shift with greater exposure to effective technology-enabled practice.

This distinction should not imply that teachers who employ student-centered instructional practices are necessarily better teachers than teachers who maintain a teacher-centered classroom. However, a body of research led by Ertmer shows that student-centered beliefs are correlated with more effective technology-enabled instructional practice when compared with teacher-centered beliefs. Teacher-centered beliefs sometimes pose a barrier to technology integration because the instructional models used by these teachers are perceived to benefit less from the use of technology. In an example cited by Tondeur and colleagues (2016), science teachers did not see a need to use technology when their primary pedagogy was direct instruction. For that purpose, technology did not offer an advantage over a blackboard or whiteboard (Donnelly et al., 2011).

Further, there is not always a direct relationship between belief and practice. Significantly, Ertmer and colleagues (2012) cite studies showing that teachers who hold student-centered beliefs do not always use technology for student-centered learning, instead using computers to fill time or for practice and drill exercises, for example. The researchers suggest that this difference between beliefs and practice correlates with the presence of particular external barriers, such as a curriculum that does not permit the use of technology for higher order thinking skills development. In such a context, using technology in a constructivist way would require the teacher to actively dismiss the assigned curriculum.

Systems leaders can also play an important role in supporting teachers' use of technology-enabled instructional practices—not only by reducing or eliminating first-order barriers but also by helping to change teachers' beliefs and attitudes.

Tondeur and colleagues also make clear that belief and practice are bidirectional and remain fluid and flexible; they explain, "Technology-rich learning experiences have the potential to change teachers' beliefs towards more student-centered, constructivist beliefs, while at the same time, teachers with constructivist beliefs are more likely to adopt technology in student-centered ways within the context of teaching and learning" (Tondeur et al., 2016, p. 562). In other words, student-centered beliefs correlate with technology-enabled teaching, but teachers' general pedagogical beliefs and their beliefs about technology-enabled teaching and learning can also shift with greater exposure to effective technology-enabled practice.

There are many other factors that can influence teachers' beliefs. Some beliefs are core, and others are more peripheral (Fives & Gill, 2015; Richardson, 1996). Some beliefs relate to value, while others relate to ability (Cheng et al., 2020; Ertmer & Ottenbreit-Leftwich, 2010; McCulloch et al., 2018; Willis et al., 2019; Xie et al., 2023). Sometimes a teacher might subscribe to a certain pedagogical belief but use practices that do not match the belief. And finally, first-order barriers may influence a teacher's practice regardless of whether the teacher's pedagogical beliefs support the use of technology (e.g., Ertmer et al., 2015; Windschitl & Sahl, 2002).

How do those factors work together to change teachers' pedagogical beliefs and technology-enabled instructional practices? Table 3 presents generalized findings about the factors that have been shown to influence teachers' pedagogical beliefs and resulting technology-enabled teaching practices.

Table 3. Factors Influencing Teachers' Beliefs and Practices

Influence on teachers' beliefs and practices	Examples
Teachers see evidence that technology-enabled teaching and learning can be used to improve student learning outcomes. (Geier et al., 2008; Ertmer et al., 2012; Ertmer & Ottenbreit-Leftwich, 2010)	A peer shares with a teacher on their team that their students experienced more growth than would be possible with nontechnological approaches in one particular competency area after they introduced a particular technology-enabled instructional practice. Teachers compare student achievement data shared at a grade-level planning meeting, and a teacher sees evidence of growth in a particular area after a technology-enabled instructional practice was introduced.
Teachers see evidence that technology-enabled teaching and learning can be used to improve learning processes or address other school or district goals. (Ertmer, 2005; Ifinedo et al., 2020; Mouza, 2009; Xie et al., 2023)	Decision-makers (including teachers) select and use technology to advance a particular district or school priority, and alternative uses of the tool are presented only after integration is achieved to advance that goal. Teachers see evidence that a particular technology or technology-enabled instructional practice allows them to achieve a teaching and learning goal, such as scaffolding, accommodation of individual student needs, or access to authentic and relevant digital sources.
Teachers have a chance to experiment with technology and experience small, incremental instructional "wins." (Ertmer, 2005; Tondeur et al., 2016; Xie et al., 2023)	Teachers improve their self-confidence, self-efficacy, and perceived technical knowledge when they are allowed to experiment with technologies that are being considered, that have been selected by a school or district, or that peer teachers are using. Teachers overcome the "lack of time" first-order barrier by introducing a small technology-enabled instructional practice that helps them achieve their instructional goals.

Influence on teachers' beliefs and practices	Examples
Teachers have meaningful, relevant, ongoing, and supportive professional learning opportunities. (An & Reigeluth, 2012; Ertmer, 2005; Ertmer et al., 2012; Kopcha et al., 2020; UNESCO, 2018)	School leadership supports a professional learning community (PLC) that is not evaluative, is not focused on a particular tool, and provides leadership opportunities for classroom teachers to share best practices for technology-enabled instruction to support a particular school or district goal. School-organized professional development sessions and ongoing support focus on technology-enabled instructional practices to achieve particular teaching goals rather than on the mechanics of how to use a particular tool.
First-order barriers such as little access to technology or unsupportive leadership are lessened or removed entirely, though there may be a lag in belief shift. (Hew & Brush, 2007; Kopcha et al., 2020; Lowther et al., 2008; Xie et al., 2023)	Technology-enabled teaching involves teachers in the selection of tools and identification of instructional practices rather than these selections coming from school or district leaders. Those tools and practices are responsive to the teachers' beliefs and the contexts of their schools. Schools or districts provide time for teachers to learn, implement, and evaluate technology-enabled instruction.

Strategies for Systems Leaders to Support Technology-Enabled Teaching

Systems leaders can also play an important role in supporting teachers' use of technology-enabled instructional practices—not only by reducing or eliminating first-order barriers but also by helping to change teachers' beliefs and attitudes. To be sure, first- and second-order barriers will remain. Different systems will require different timelines. But systems leaders can help foster real change in how teachers perceive and use technology to advance learning (e.g., Lim & Khine, 2006; Perrotta, 2013; Somekh, 2008; Tearle, 2004).

To do so, systems leaders can consider three influences on teachers' existing beliefs concerning technology-enabled teaching and learning, as identified in the literature: personal experiences, vicarious experiences, and social–cultural influences (Ertmer, 2005). As shown in Figure 2, systems leaders are well positioned to effect change in all three areas.

Figure 2. Influences That Can Successfully Challenge Teachers' Existing Beliefs

Providing Personal Experiences	Providing Vicarious Experiences	Fostering Social–Cultural Influences
For example, a principal suggests a technology-enabled instructional practice to a teacher. The teacher has a positive personal experience with that practice.	For example, a principal pairs a teacher with a peer. The peer teacher explains the positive impact of a technology-enabled instructional practice.	For example, a district leader organizes a professional learning community that elevates the voices of teachers in discussing technology-enabled instruction.

Whatever strategy systems leaders use, much of their work can begin with understanding the context, barriers, and conditions that operate at an individual school or district and meeting individual teachers where they are. Systems leaders can take a number of steps to encourage shifts in teachers' beliefs and practices. The following strategies are adapted from a number of peer-reviewed articles discussing the importance of institutional leadership for technology-enabled teaching practice (e.g., Ertmer, 2005; Perrotta, 2013) and from examples sourced from practitioners and experts conducting work about technology-enabled teaching in the field (e.g., P. Moyle, personal communication, December 2022).

Align school or district vision, priorities, and plans with technology-enabled instructional approaches: Technology is not valuable in and of itself, and teachers' pedagogical beliefs and instructional practices do not shift simply because technology is available. Instead, technology must be shown to be useful to advance shared goals. For example, if a district's strategic plan or vision stresses the importance of serving English language learners equitably, plans for technology-enabled instruction should help further that particular vision.

Articulate the benefits of specific technology-enabled instructional practices in comparison with traditional techniques: Support for technology in general or for technology-enabled instructional practices is worth very little if teachers do not see how these practices create advantages that could not be achieved through traditional approaches. For example, a systems leader might highlight how a teacher is using a particular set of vetted OER materials to further learning on a topic that received only superficial treatment in a textbook. Or a systems leader might provide access to a standards-aligned virtual field trip that can also foster global awareness and real-world learning.

Demonstrate how technology-enabled, student-centered learning has meaningfully improved learning outcomes—and when it has not: Not all technology-enabled instructional practices are worth pursuing. But systems leaders can play a role in identifying those instructional practices that have been shown to positively impact learning processes and student performance. Systems leaders can do so by drawing on external sources such as instructional frameworks and technology integration frameworks as well as the literature on technology-enabled teaching and learning. Impactful instructional practices can also be identified within a school community itself. Teachers who have implemented a new practice or who have participated in a school or district pilot can share with other teachers what they are learning and the gains that they have seen.

At the same time, it is important that systems leaders create an environment in which teachers feel safe sharing frustrations or discussing areas where technology-enabled instruction or particular technological tools have *not* provided benefits. In such cases, teachers and administrators can work together to devise suggestions for improved practice or to reevaluate purchasing decisions.

Provide vicarious opportunities for teachers to see the utility of technology-enabled instruction in context-responsive ways: Systems leaders can make sure that professional learning opportunities align with a school's or district's vision or goals. But other types of contexts are also important. For example, a teacher may value certain pedagogies above others or may perceive their own technological knowledge as subpar. Leaders can provide teachers with opportunities to articulate those values and perceived skills and then offer opportunities for teachers to observe other teachers with similar values who use technology-enabled instructional practices effectively and in ways that do not require significant technical knowledge. This incremental approach acknowledges the legitimacy of the teacher's position and can help move both belief and practice over time rather than insisting on a student-centered approach or the immediate use of technology to advance that approach.

Support social–cultural spaces that promote effective technology-enabled teaching and learning: Systems leaders can create and nurture a set of social–cultural influences that promote effective technology-enabled instruction. Many of these spaces do not require significant resources. For example, a school leader might support a teacher-run PLC to discuss technology-enabled instruction.

Other types of influences may require more resources. For example, an instructional coach may be deployed to different classrooms to work with teachers on effective instructional practices or to help teachers parse learning data generated through the use of technological platforms. In any case, such programs or personnel must be available in an ongoing manner and offered in the context of support rather than evaluation.

For all of these approaches, context matters deeply. That principle also applies to the way that technology-enabled instruction is deployed in different countries. Policies, structures, aims, resources, and barriers will operate differently in different places (see, for example, In et al., 2018). The following are just some of the factors that are important to consider when evaluating strategies to propel effective technology-enabled teaching and learning internationally:

- policy environment
- centralization of educational technology selection and integration
- resources of schools and prevalence of first-order barriers
- curricula, requirements, and pedagogies taught in teacher training programs
- local effect of COVID-19 pandemic and the degree of “learning loss” experienced
- teachers’ comfort with, understanding of, and knowledge about technology

Conclusion

There is no one correct way to "do" technology-enabled instruction or to support it. Instead, system-directed strategies to promote effective technology-enabled instruction must begin with a careful assessment of the contexts in which individual teachers operate.

What resources are available? What barriers exist? What pedagogical beliefs and values do teachers hold? What are the specific areas in which technology-enabled instruction benefits student learning or advances district or school priorities?

Different school communities will have different answers to these questions. In some cases, school leaders may not have ready answers. The investigative process is part of the work of realizing technology's possibilities—and drawbacks—within particular contexts.

As indicated in this thought piece, there are numerous resources to aid in that task; frameworks abound both for technology integration and for tool selection and also for instructional practices based in the learning sciences. What is missing is a bridge between these two areas of effort. Ideally, a single entity could facilitate conversation between the two areas while also allowing for communication between the myriad actors who set the conditions that contribute to teachers' beliefs and practices: school principals, superintendents, district technology leaders, district academic leaders, instructional coaches, peer teachers, curriculum developers, technology developers, and others.

Armed with the research about why and how to encourage effective technology-enabled instruction in K–12 education, it is time to think about what that bridge between technology integration and instructional practice might look like. The pieces exist, but they need to be put together in ways that are easy to operationalize and that are rigorous, flexible for a variety of contexts, and supportive of teachers and teaching. At the core of effective technology-enabled instruction is good teaching, and teachers need to play a central role in envisioning how technology-enabled instruction can advance positive learning outcomes in their school communities.

References

Ainley, M. (2006). Connecting with learning: Motivation, affect and cognition in interest processes. *Educational Psychology Review*, *18*(4), 391–405.

An, Y., & Reigeluth, C. (2012). Creating technology-enhanced, learner-centered classrooms: K–12 teachers' beliefs, perceptions, barriers, and support needs. *Journal of Digital Learning in Teacher Education*, *28*(2), 54–62.

Bešić, E. (2020). Intersectionality: A pathway towards inclusive education? *Prospects*, *49*, 111–122.

Bienkowski, M., Feng, M., & Means, B. (2012). *Enhancing teaching and learning through educational data mining and learning analytics: An issue brief*. U.S. Department of Education, Office of Educational Technology. https://tech.ed.gov/wp-content/uploads/2014/03/edm-la-brief.pdf

Cambridge International Education Teaching and Learning Team. (n.d.). *Getting started with assessment for learning*. Cambridge University Press & Assessment. https://cambridge-community.org.uk/professional-development/gswafl/index.html

Carnevale, A. P. (2013). *21st century competencies: For college and career readiness*. Center on Education and the Workforce, Georgetown University. https://repository.library.georgetown.edu/handle/10822/559289

CAST. (2018). *Universal design for learning guidelines version 2.2* [Graphic organizer]. https://udlguidelines.cast.org/binaries/content/assets/udlguidelines/udlg-v2-2/udlg_graphicorganizer_v2-2_numbers-yes.pdf

Cheng, S. L., Lu, L., Xie, K., & Vongkulluksn, V. W. (2020). Understanding teacher technology integration from expectancy-value perspectives. *Teaching and Teacher Education*, *91*, 1–14.

Cohen, D. K., & Ball, D. L. (1999). *Instruction, capacity, and improvement*. CPRE Research Reports. Consortium for Policy Research in Education, Graduate School of Education, University of Pennsylvania. https://repository.upenn.edu/cgi/viewcontent.cgi?article=1073&context=cpre_researchreports

Colorado Department of Education. (2013). *21st century skills in Colorado's Reading, Writing and Communicating Standards*. https://www.cde.state.co.us/coreadingwriting/rwc_21st_century_skills

The Danielson Group. (n.d.). *The Framework for Teaching*. https://danielsongroup.org/framework/

Delgado, A. J., Wardlow, L., McKnight, K., & O'Malley, K. (2015). Educational technology: A review of the integration, resources, and effectiveness of technology in K–12 classrooms. *Journal of Information Technology Education: Research*, *14*, 397–416. https://www.researchgate.net/publication/310491597_Educational_Technology_A_Review_of_the_Integration_Resources_and_Effectiveness_of_Technology_in_K–12_Classrooms

Deng, F., Chai, C. S., Tsai, C. C., & Lee, M. H. (2014). The relationships among Chinese practicing teachers' epistemic beliefs, pedagogical beliefs and their beliefs about the use of ICT. *Journal of Educational Technology & Society*, *17*(2), 245–256.

Donnelly, D., McGarr, O., & O'Reilly, J. (2011). A framework for teachers' integration of ICT into their classroom practice. *Computers & Education*, *57*, 1469–1483.

Dorn, E., Hancock, B., Sarakatsannis, J., & Viruleg, E. (2021). *COVID-19 and education: The lingering effects of unfinished learning*. McKinsey & Company. https://www.mckinsey.com/industries/education/our-insights/covid-19-and-education-the-lingering-effects-of-unfinished-learning

Ed tech use continues growth beyond the peak of the pandemic. (2021, September 9). *THE Journal*. https://thejournal.com/articles/2021/09/09/ed-tech-use-accelerates-beyond-the-peak-of-the-pandemic.aspx

EdTech Evidence Exchange. (2021). *Overview: U.S. K–12 public education technology spending*. https://edtechevidence.org/wp-content/uploads/2021/07/FINAL-K12-EdTech-Funding-Analysis_v.1.pdf

Ertmer, P. A. (1999). Addressing first- and second-order barriers to change: Strategies for technology integration. *Educational Technology Research and Development*, *47*(4), 47–61.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 25–39.

Ertmer, P. A., Addison, P., Lane, M., Ross, E., & Woods, D. (1999). Examining teachers' beliefs about the role of technology in the elementary classroom. *Journal of Research on Computing in Education*, *32*(1/2), 54–72.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*, 255–284.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education*, *64*, 175–182. https://doi.org/10.1016/j.compedu.2012.10.008

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423–435.

Ertmer, P. A., Ottenbreit-Leftwich, A. T., & Tondeur, J. (2015). Teacher beliefs and uses of technology to support 21st century teaching and learning. In H. Fives & M. G. Gill (Eds.), *International handbook of research on teachers' beliefs* (pp. 403–418). Routledge.

Fives, H., & Gill, M. G. (Eds.). (2015). *International handbook of research on teachers' beliefs*. Routledge.

Freeland Fisher, J. (2018, September 18). Why a web of connections—not a single relationship—should surround students. *EdSurge*. https://www.edsurge.com/news/2018-09-28-why-a-web-of-connections-not-a-single-relationship-should-surround-students

Friday Institute for Educational Innovation. (2018). *North Carolina digital learning plan: Digital learning progress rubric for schools*. North Carolina State University. https://www-data.fi.ncsu.edu/wp-content/uploads/2021/03/01123458/school.pdf

Ganimian, A. J., Vegas, E., & Hess, F. M. (2020). *Realizing the promise: How can education technology improve learning for all?* Brookings. https://www.brookings.edu/essay/realizing-the-promise-how-can-education-technology-improve-learning-for-all/

Geier, R., Blumenfeld, P. C., Marx, R. W., Krajcik, J. S., Fishman, B. J., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students involved in inquiry-based science curricula in the context of urban reform. *Journal of Research in Science Teaching*, *45*, 922–939.

Harackiewicz, J. M., Smith, J. L., & Priniski, S. J. (2016). Interest matters: The importance of promoting interest in education. *Policy Insights From the Behavioral and Brain Sciences*, *3*(2), 220–227.

Hew, K. F., & Brush, T. (2007). Integrating technology into K–12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, *55*, 223–252.

Ifinedo, E., Rikala, J., & Hämäläinen, T. (2020). Factors affecting Nigerian teacher educators' technology integration: Considering characteristics, knowledge constructs, ICT practices and beliefs. *Computers & Education*, *146*(1), Article 103760.

In, H., Byun, S., & Shin, W. (2018). A comparative study of factors associated with technology-enabled learning between the United States and South Korea. *Educational Technology Research and Development*, *66*, 1303–1320.

Johnson, L., Levine, A., Smith, R., & Stone, S. (2010). *The 2010 Horizon Report*. The New Media Consortium. https://library.educause.edu/-/media/files/library/2010/1/csd5810-pdf.pdf

Jonassen, D. H. (1996). *Computers in the classroom: Mindtools for critical thinking*. Prentice-Hall.

Jones, S. E., Ethier, K. A., Hertz, M., DeGue, S., Le, V. D., Thornton, J., Lim, C., Dittus, P. J., & Geda, S. (2022). Mental health, suicidality, and connectedness among high school students during the COVID-19 pandemic—Adolescent Behaviors and Experiences Survey, United States, January–June 2021. *Morbidity and Mortality Weekly Report*, *71*(Suppl-3),16–21. https://www.cdc.gov/mmwr/volumes/71/su/su7103a3.htm

Kirkwood, A., & Price, L. (2016). *Technology-enabled learning implementation handbook*. Commonwealth of Learning. https://oasis.col.org/colserver/api/core/bitstreams/141fd9a1-d247-49a8-a1d1-6ec5f15841ba/content

Klein, A. (2021, April 20). During COVID-19, schools have made a mad dash to 1-to-1 computing. What happens next? *Education Week*. https://www.edweek.org/technology/during-covid-19-schools-have-made-a-mad-dash-to-1-to-1-computing-what-happens-next/2021/04

Kopcha, T. J., Neumann, K. L., Ottenbreit-Leftwich, A., & Pitman, E. (2020). Process over product: The next evolution of our quest for technology integration. *Educational Technology Research and Development*, *68*(2), 729–749.

Kurtz, H., Lloyd, S., Harwin, A., Chen, V., & Furuya, Y. (2020). *Crisis of confidence: Results of national surveys on educator morale during a pandemic*. EdWeek Research Center. https://epe.brightspotcdn.com/30/0f/f279dc9b4a1fb706e988c1577870/crisis-of-confidence-final-6.29.20.pdf

Lewin, C., Smith, A., Morris, S., & Craig, E. (2019). *Using digital technology to improve learning: Evidence review*. Education Endowment Foundation. https://educationendowmentfoundation.org.uk/education-evidence/evidence-reviews/digital-technology-2019

Lim, C. P., & Khine, M. (2006). Managing teachers' barriers to ICT integration in Singapore schools. *Journal of technology and Teacher Education*, *14*(1), 97–125.

Lowther, D. L., Inan, F. A., Daniel Strahl, J., & Ross, S. M. (2008). Does technology integration "work" when key barriers are removed? *Educational Media International*, *45*(3), 195–213.

McCulloch, A. W., Hollebrands, K., Lee, H., Harrison, T., & Mutlu, A. (2018, August). Factors that influence secondary mathematics teachers' integration of technology in mathematics lessons. *Computers & Education*, *123*, 26–40.

Means, B., & Olson, K. (Eds.). (1997). *Technology and education reform*. National Academies Press, Office of Educational Research and Improvement, U.S. Department of Education.

Mervosh, S. (2022, September 1). The pandemic erased two decades of progress in math and reading. *The New York Times*. https://www.nytimes.com/2022/09/01/us/national-test-scores-math-reading-pandemic.html

Moore, K. (2016, April 7). Study: 73% of employers want candidates with this skill. *Inc.* https://www.inc.com/kaleigh-moore/study-73-of-employers-want-candidates-with-this-skill.html

Mouza, C. (2009). Does research-based professional development make a difference? A longitudinal investigation of teacher learning in technology integration. *Teachers College Record*, *111*(5), 1195–1241.

Natanson, H. (2022, August 4). "Never seen it this bad": America faces catastrophic teaching shortage. *The Washington Post*.

National Commission on Social, Emotional, & Academic Development. (2019). *From a nation at risk to a nation at hope*. Aspen Institute. https://files.eric.ed.gov/fulltext/ED606337.pdf

Neuman, S. (2022, November 13). The culture wars are pushing some teachers to leave the classroom. *NPR*. https://www.npr.org/2022/11/13/1131872280/teacher-shortage-culture-wars-critical-race-theory

Newhouse, C. P. (2001). A follow-up study of students using portable computers at a secondary school. *British Journal of Educational Technology*, *32*(2), 209–219.

Office of Educational Technology. (2017). *Reimagining the role of technology in education: 2017 National Education Technology Plan update*. U.S. Department of Education. https://tech.ed.gov/files/2017/01/NETP17.pdf

Pape, B. (2018). *Learner variability is the rule, not the exception*. Digital Promise Global. https://digitalpromise.org/wp-content/uploads/2018/06/Learner-Variability-Is-The-Rule.pdf

Pape, B., & Vander Ark, T. (2018). *Making learning personal for all: Policies and practices that meet learners where they are*. Digital Promise Global. https://digitalpromise.org/wp-content/uploads/2018/01/lps-policies_practices-r3.pdf

Perrotta, C. (2013). Do school-level factors influence the educational benefits of digital technology? A critical analysis of teachers' perceptions. *British Journal of Educational Technology*, *44*(2), 314–327.

Proctor, S. L., Williams, B., Scherr, T., & Li, K. (2017). *Intersectionality and school psychology: Implications for practice*. National Association of School Psychologists. https://www.nasponline.org/resources-and-publications/resources-and-podcasts/diversity-and-social-justice/social-justice/intersectionality-and-school-psychology-implications-for-practice

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102–119). Simon & Schuster/Macmillan.

Roehlkepartain, E., Pekel, K., Syvertsen, A., Sethi, J., Sullivan, T., & Scales, P. (2017). *Relationships first: Creating connections that help young people thrive*. Search Institute. https://www.search-institute.org/wp-content/uploads/2017/12/2017-Relationships-First-final.pdf

Rose, T. (2016). *The end of average: How to succeed in a world that values sameness*. HarperOne.

Shao, Y., & Kang, S. (2022). The association between peer relationship and learning engagement among adolescents: The chain mediating roles of self-efficacy and academic resilience. *Frontiers in Psychology*, *13*, Article 938756. https://doi.org/10.3389/fpsyg.2022.938756

Somekh, B. (2008). Factors affecting teachers' pedagogical adoption of ICT. In J. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education*, 449–460. Springer.

Tearle, P. (2004). A theoretical and instrumental framework for implementing change in ICT in education. *Cambridge Journal of Education*, *34*(3), 331–351.

Terada, Y. (2020). SAMR: A powerful model for understanding good tech integration. *Edutopia*. https://www.edutopia.org/article/powerful-model-understanding-good-tech-integration/

Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2016). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, *65*(3), 555–575.

United Nations Educational, Scientific, and Cultural Organization. (2018). *UNESCO ICT Competency Framework for Teachers*. https://unesdoc.unesco.org/ark:/48223/pf0000265721

Willis, R., Lynch, D., Fradale, P., & Yeigh, T. (2019). Influences on purposeful implementation of ICT into the classroom: An exploratory study of K–12 teachers. *Education and Information Technologies*, *24*(1), 63–77.

Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal*, *39*(1), 165–205.

Xie, K., Nelson, M. J., Cheng, S.-L., & Jiang, Z. (2023). Examining changes in teachers' perceptions of external and internal barriers in their integration of educational digital resources in K–12 classrooms. *Journal of Research on Technology in Education*, *55*(2), 281–306. https://doi.org/10.1080/15391523.2021.1951404

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record*, *104*(3), 482–515.

Appendix: Background for Developing This Thought Piece

Owing to the rapidity of change in digital technology and schools' adoption of digital technology—as well as the profound shifts that came from the COVID-19 pandemic—this thought piece relies on a variety of sources, including both peer-reviewed literature and examples from contemporary practice.

The research team for this thought piece assessed peer-reviewed literature that was collected in fall 2022 and accessed through a number of online databases, including Google Scholar, EBSCO, ERIC, JSTOR, and ResearchGate. Keyword searches for articles published from 2000 to 2022 were conducted in Google Scholar and JSTOR. The research team used the following keywords: technology-enabled teaching, technology-enabled instruction, technology-enabled learning, technology-enhanced teaching, technology-enhanced learning, learner variability, personalized learning, teaching with educational technology, technology integration in education, K–12 instructional practice, K–12 technology integration, K–12 digital learning, and K–12 learning analytics.

The team also conducted searches for work by prominent scholars in the field. References appearing on multiple collected articles were also examined. The team reviewed articles if they were in English, specific to K–12 education, had citation counts numbering above a dozen, and/or were cited by other articles in the review. From these, around two dozen articles that were particularly pertinent for this thought piece were examined more completely.

In addition, to identify reports that were not peer-reviewed, the research team conducted general Google searches for the keywords named above. The team also examined reports available on the websites of relevant professional organizations in the United States and the United Kingdom. The research team collected news articles, surveys, and other materials documenting more recent attitudes and trends about technology-enabled teaching and learning. Altogether, around a dozen reports and news articles were examined more completely.

Finally, the research team collected and analyzed contemporary examples and resources from the field. These included widely used technology integration frameworks and widely used instructional frameworks. In addition, the research team consulted three experts to supply and critique contemporary examples from the field: Patrick Moyle, Distance Learning Architect and Professional Learning Specialist at WestEd; Carmalita Seitz, Certification Director at ISTE; and Carolyn Sykora, Senior Director of ISTE Standards Programs.