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Three Domains for Technology Integration in Science Teacher Education

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The science teacher education community plays a prominent role in teacher preparation programs. Particularly, science methods courses emphasize modeling instructional strategies to promote inquiry-based practices. Integrating appropriate educational technology to enhance and support classroom practices should be embedded in these courses. The recommendations in this paper, specific to science methods, consist of designing the proper use of educational technology using three domains: (a) supporting the process of learning, (b) catalyzing the acquisition of information, and (c) communicating acquired knowledge. The three proposed domains are illustrated at different levels of the PICRAT technology integration model (Kimmons, 2016), with examples that can be quickly adapted to both elementary and secondary science methods courses. The authors aim to help inform science methods instructional practice, the design of related activities, and the application of education technology.

This pedagogical position paper proposes three domains for the integration of technology and science in science teacher education. We argue that science teachers must use technology to (a) support the navigation and process of learning, (b) catalyze the acquisition of information and new understandings, and (c) communicate scientific knowledge and understanding. Ultimately, by demonstrating the vitality of digital technology to science teacher education, we hope to reaffirm the science-technology bond in experiential science learning and teaching practices.

Historically, science and technology have enjoyed a symbiotic relationship. The observation and creativity of science has incited advances in technology that have, in turn, inspired advances in science. Technology involves "the application of knowledge, tools, and skills to solve practical problems and extend human abilities" (Johnson, 1989, p. 1).

The lens, itself a creation of science, led to the development of the microscope and telescope, opening entirely new worlds, cosmic and microscopic, for exploration. The science-technology bond is no different today: The leading edges of science still venture into the study of the very large, such as black holes, and the very small, such as quantum physics. Scientific knowledge is built on the collection and analysis of data and the communication of findings, all of which occur through technology. Science, with its rigorous empiricism and dedication to forward movement, has fed technology's hunger for invention; advances in technology have, in turn, inspired the science responsible for its creation. Scientific examination of phenomena demands hands-on experience, which finds a supportive partner in technology.

This relationship has been articulated in educational policy documents as early as the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science, 1993) and the *National Science Education Standards* (National Research Council, 1996). Interactive models of scientific phenomena — mitosis, electron movement, climate change, orbits of the planets — inspire students to formulate questions, plan and carry out investigations, collect and interpret data, construct explanations, engage in argumentation, and communicate information (Lee, 2017). It is, thus, a disservice to students when the experiential component of science learning does not take advantage of the affordances of technology.

The separation of technology from science learning is especially disadvantageous today amid the climate of proliferating digital technology. For example, virtual experiments via simulation software, modeling with the use of extended reality, and accessible as well as varied formative assessment tools all have the potential to make science education more efficient for the teacher and more engaging for the learner. These examples of technologies that support science learning are distinct from more generic, content-agnostic technologies for learning (such as learning management systems, video conferencing software, and productivity/collaboration tools). While such instructional technologies can support teaching and learning in innovative ways, we direct our focus in this work toward technologies allowing science educators to leverage technology meaningfully in service of science specific learning.

The Role of Technology in Science Education

Science teacher educators around the world have adopted a variety of approaches to integrating technology into their science teacher education programming. A good place to start examining the role of technology in science education is with teacher licensure requirements. These requirements provide some insight into how different countries and regions emphasize the various aspects of teacher preparation, as they place different requirements on the content knowledge, pedagogical knowledge, and the technological knowledge required of teachers of science.

In North America, for the preparation of elementary teachers, the focus leans heavily toward pedagogy (Lewis et al., 2014). A limited amount of science content is required and more often than not, no explicit requirements are established for preparation around the use of technology connected to science pedagogies.

Secondary teacher preparation licensure tends to flip the emphasis to science content knowledge. The content knowledge requirements are high due to the mix of general science and subject-specific science content required for licensure. Emphasis on technological knowledge is limited, however, and it is inconsistently applied across programs (Olson et al., 2015).

In Asia, an area known for high education standards, the role of technology is varied. In Korea, the split is consistent, as two thirds of teacher preparation focuses on content knowledge, and one third focuses on pedagogy. Technology preparation is not a specific requirement (Center on International Education Benchmarking, 2022). Thailand has two accrediting bodies for teacher preparation, both of which are focused on professional knowledge and experience, practice, and ethics. The use of technology in education is one of the nine focus areas of professional knowledge and experience. There are also specific standards for science teachers that include the ethical use of science and technology (Faikhamta et al., 2018). Japan has a consistent requirement for technology, as all teacher preparation programs require a two-credit class on the use of information devices, like tablet computers and smart phones.

The Role of Technology in Science Teacher Education/Preparation

Although educators have pondered the role of technology in science education for decades (e.g., Johnson, 1989; Thornburg, 1999), many preservice science teachers still struggle to integrate technology effectively with their instruction (Hechter et al., 2012; Svihla et al., 2015). A science educator preparation program is an ideal place to support teacher candidates' integration of technology in P-12 science classrooms (Foulger et al., 2017). Teacher preparation programs are highly formative experiences for new teachers that guide inquiry and strengthen both content learning and pedagogical strategies (Darling-Hammond & Bransford, 2005).

Discerning "how teachers learn to engage in practices that successfully support student development and learning" (Darling-Hammond & Bransford, 2005, p. 25) and how to teach science in changing times calls for a new type of innovation to foreground the necessary skills. Fundamentally, science education reforms across the globe always strive to achieve high-quality science teaching (Next Generation Science Standards [NGSS] Lead States, 2013). As educators to the next generation of science teachers and teachers who teach science, teacher educators play a critical role in implementing any of those science education reforms (Bybee, 2014). Teachers today are then expected to leverage these modern technologies into their pedagogical strategies to meet their learners' needs (Kang et al., 2010).

Personal, new, and positive experiences gained during science methods courses help support the self-efficacy of future science teachers (Menon & Sadler, 2016; Palmer, 2006). Teachers' science teaching beliefs influence their (a) instructional decisions and learning (Rubie-Davies et al., 2012), (b) implementation of content and/or curricula in a classroom (Luft, 1999; Roehrig et al., 2007), and (c) reasons for engaging in certain type of science teaching practices, such as inquiry (Subramaniam et al., 2018).

Science teacher educators have supported technology integration initiatives in a variety of ways: They may craft experiences that help their teacher candidates use technology effectively in the classroom (Habowski & Mouza, 2014), understand the affordances and limitations of technology (Kirschner et al., 2004), or create a personal vision for teaching and learning with technology (Hechter, 2012). No matter the approach, it is critically important to understand what view of technology the science teacher education program advances.

Honey et al. (2014) identified three views on technology in the science/STEM (science, technology, engineering, and mathematics) classroom: (a) technology as the product of engineering (i.e., vocational technology and shop class), (b) technology as educational/instructional technology (e.g., clickers, SMARTboards, and internet-capable devices), and (c) technology as the tools of practitioners of science, mathematics, and engineering. This third view was the focus of our work, as this perspective has the greatest potential to impact science learning positively (Ellis et al., 2020).

Technology as the Tools of Practitioners of Science, Mathematics, and Engineering

As technology use and the work of professional scientists is intertwined, science educators can use the same, or analogous, technologies in the classroom to promote learning that "closely emulates how scientists work in the real world. Students can collect and analyze real-time data much like scientists do" (Novak & Krajick, 2006, p. 76). Bell and Bull (2008) also suggested that technology should be used in a science classroom "to facilitate data collection and analysis, to enhance scientific understanding through imagery and visualization, and to extend inquiry through communication and collaboration" (p. 92). In fact, most methodologies of the application of science in the classroom can be categorized into four areas: (a) gathering scientific information, (b) collecting and analyzing data, (c) creating and using models of scientific phenomena, and (d) communicating findings (Ekici & Erdem, 2020; Park & Slykhuis, 2006).

For example, Horjesi (2019) explained the way that using a hand dynamometer increased engagement and allowed students to collect real-time data, visualize the data, make predictions, test variables and form conclusions as a real scientist would. Flick and Bell (2000) proposed five guidelines for the use of technology in science education:

- Technology should be introduced in the context of science content.
- Technology should address worthwhile science with appropriate pedagogy.
- Technology instruction in science should take advantage of the unique features of technology.
- Technology should make scientific views more accessible.
- Technology instruction should develop students' understanding of the relationship between technology and science.

Technology enhances the science teacher education experience when it is closely tied to the lived realities of scientists and the constructed experiences of the learner. To increase science teacher candidates' efficacy, science teacher educators should employ technology in their classes through three distinct domains: (a) supporting the navigation and process of learning, (b) catalyzing the acquisition of information and new understandings, and (c) communicating scientific knowledge and understanding. Each of these domains will be discussed in the following sections and then explored using the PICRAT framework.

Supporting the Navigation and Process of Learning

The use of learning management systems has become ubiquitous (and is not unique to science classrooms), but the development of technologies that support the navigation of inquiry in various settings is in the interest of the science teacher — and, thus, to the science teacher educator. Technologies, including learning management systems, data collection and analysis software, and communication tools, allow the teacher to promote inquiry throughout the learning process. These technologies support sustained engagement throughout the learning process by increasing both effective communication among learners and instructors and intrinsic motivation for the learners. With forethought and planning, the science teacher educator can utilize technologies that are common in STEM fields as well as in digital-age learning environments, making the learning experience of future science teachers more authentic to real science practices.

Science instruction is best when carried out with intentionality. Science instruction for future science teachers also must be carried out with intention and explicit focus on authentic inquiry and investigation. In designing learning experiences for future teachers, science teacher educators first evaluate the end goals of the learning experience and then align the goals with assessments. Pedagogical strategies are then chosen to develop the knowledge and understandings of science teacher candidates to meet the goals and succeed at the assessments (Wiggins & McTighe, 1998; Wiggins et al., 2005). Pedagogies that include technology and investigatory experiences — in other words, hands-on pedagogies — are inherently engaging for students no matter the grade level and lead to more-successful science learning experiences.

Catalyzing the Acquisition of Information and New Understandings

One way to promote the acquisition of information and new understandings is through the 5E learning cycle (Bybee, 2014; Bybee et al., 2006). In this template, the integral part of the learning cycle is that the students have engaging hands-on-with-minds-on experiences. These hands-on experiences replicate the actions of a scientist as Honey et al. (2014) suggested and can happen on a nonlinear learning path. (Although the 5E learning cycle does not have to be implemented in a linear fashion, it is often communicated that way.)

The first step is the Engage phase, the “hook” to the lesson, wherein the students’ prior knowledge is activated. The second step is the Explore phase, where students perform experimentations and collect information. This phase is followed by the Explain phase, in which the learners explain what they discovered in the explore step and the instructor connects the activity to academic science content. Next is the Elaborate phase, which connects in-class learning with the real-world context. Last is the Evaluate phase, where formal assessment takes place.

Technology can easily be infused into any of these steps. For example, technology can demonstrate and model scientific concepts as well as support the collection and analysis of data throughout the learning experience. Teacher educators can use technology to engage future science teachers as they model innovative practices tied to proven pedagogies. Involving teacher candidates in meaningful learning experiences that invite them to use educational technology can help these instructional practices to develop and be refined over time through practice.

Communicating Scientific Knowledge and Understanding

In addition to acquiring and understanding scientific knowledge, communication of understanding and scientific findings is a critical component of the work of a scientist (Baram-Tsabari & Osborne, 2015). Educators can avail themselves of tools that allow them to disseminate and impress scientific knowledge and content in innovative and indelible ways.

Technology tools today allow students to communicate both within and beyond their classroom in ways that were not previously possible. Within a classroom, it is possible for teachers and students to project information onto either a large screen or a variety of devices. In this way, students can display data they have collected to the class, and their peers can examine the data and even add their own data to a larger classroom set. Students can also quickly share information in the classroom digitally through a classroom learning management system (LMS) that may have a discussion feature allowing collaboration across working groups.

Perhaps even more powerfully, teacher educators can engage their students to share outside the classroom. Public posting can be created using a simple blog-style website, video sharing, or podcasting. All of these outlets make the scientific inquiry process more authentic with the publication of data allowing for outside comment and critique.

Connecting Pedagogy, Technology, and Science Teacher Education

When preparing teacher candidates to teach science in P-12 schools, teacher educators embody the practices of science instruction and model best practices for future science teachers (Gess-Newsome, 2002). Teacher educators share both the challenge and the potential of educational technologies used in the learning context, ultimately contextualizing technology and the relevant competencies needed to teach science content. Remillard (2005) argued that teachers' engagement with curriculum materials is shaped by the teachers' own resources and the resources in the curriculum materials, and this participation shapes the planned and, in turn, enacted practice in the classroom.

The teachers' science subject-matter knowledge, including their understanding of science concepts and practices, is a key resource on which they will draw upon in instruction. Therefore, teacher candidates engaged in enacting the lessons with the use of technology will help solidify active instructional practices. An increase in their exposure to and training in educational technology in education preparation programs will foster their confidence in the role of technology to enhance content teaching and instructional practices.

Our proposed three domains of science teacher educator technology application align with models of practice we encourage teacher educators to employ. Modeling effective planning and implementation of technology-enhanced science learning experiences is essential to supporting the navigation and process of learning. The experience of learning science in tandem with technologies allows teacher candidates to engage in their own pedagogical inquiry. Through methods courses and clinical experiences that make relevant science content and science learning, technologies can support the development of, and instill purpose in, preservice science teacher candidates (Lux, 2015).

This work provides an essential starting point in designing the proper use of educational technology, with the specific purpose of responding to the needs of science educators and learners. It will also leverage applicable technology integration frameworks and describe how science teacher educators can integrate technology in their teaching. In particular, the PICRAT model (Kimmons, 2016) will be invoked to examine how this integration can make classroom activities both more student centered and transformative.

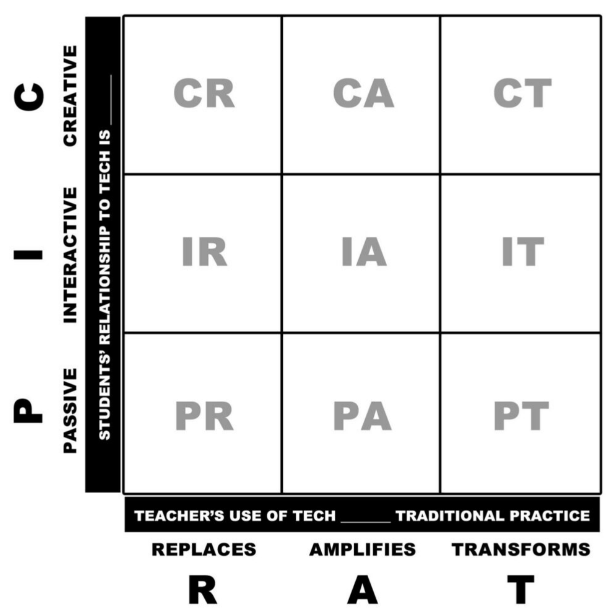
Alignment of Domains to the PICRAT Model

Many models for technology integration exist, including TPACK (Mishra & Koehler, 2006), Triple E (Kolb, 2017), RAT (Hughes et al., 2006) and PICRAT (Kimmons et al., 2020). In addition to these models, educators can also look to such frameworks as the International Society for Technology in Education (ISTE) Standards (ISTE, 2020) and the Teacher Educator Technology Competencies (Foulger et al., 2017) for guidance.

Although there is no shortage of standards on, policy documents about, and theoretical frameworks for the role of technology in teacher education, only a small number of them lend themselves well to the context-specific learning that takes place in a science teacher education methods course. The PICRAT model is best suited to guide science teacher educators who wish to develop their teacher candidates' capacities for technology-integrated instruction in their future science classrooms.

PICRAT is "a student-focused, pedagogy-driven model that can be effective for the specific context of teacher education — comprehensible and usable by teachers as it guides the most worthwhile considerations for technology integration" (Kimmons et al., 2020). The letters that comprise the acronym PICRAT encompass both the students' relationship to the technology introduced by the teacher (as *passive*, *interactive*, or *creative*) and the teachers' categorical use of the technology (as *replacing*, *amplifying*,or *transforming* the teaching activity). Figure 1 depicts a matrix that illustrates the various combinations of these attributes that may be used to characterize necessary technology integration within the classroom.

Figure 1
PICRAT Model



Following are examples of technology integration that are specific to the contexts of both elementary and secondary science teacher preparation programs. These examples will represent the three domains for technology integration that comprise our model. Additionally, these examples will be aligned to the PICRAT categories of passive replacement (PR), interactive amplification (IA), and creative transformation (CT) to illustrate how examples from our domains can be mapped to this framework. While creative and transformative approaches to technology integration may hold the greatest potential for innovative science teaching, each of these approaches is capable of improving the teaching and learning that occurs in a science classroom.

Elementary Science Teacher Preparation

Supporting the Navigation and Process of Learning

Children's literature is often used in inquiry-based lessons (Morgan & Ansberry, 2017; Nesmith et al., 2017). Often at the heart of the Engage phase, books offer myriad benefits, such as inclusive narratives. As science teacher educators engage their candidates, they can model lessons and strategies that incorporate picture books, media-enhanced picture books, and options for replacing or repurposing digital picture books. An example of purposefully using technology to replace a read-aloud is *Story Time from Space* (https://storytimefromspace.com/), a platform wherein real astronauts perform read-alouds in zero gravity.

Teacher educators can train teacher candidates in how to instill an inquisitive mindset in their students. In one video that the teacher educator may show candidates, the astronaut Kate Rubins reads *Rosie Revere, Engineer* by Andrea Beaty, and students are then prompted to attempt a short engineering challenge (see Video 1). The teacher educator can use the video to guide candidates to assist students' inquiry-cultivation process. Simply weaving in literature through technology can improve this experience. Moreover, it offers a sound model for how low-stakes technology use can engage students, introduce scientific concepts, and support learning.

Video 1
Rosie Revere, Engineer

https://www.youtube.com/watch?v=r5yZ8K7pb0Y

This activity is an example of passive replacement, as the students consume the story through the use of technology and do not interact with it, making it passive. It is considered replacement, as the read-aloud online platform replaces having the students or teacher read the passage. In our domains, it is an example of a teacher educator supporting the navigation and process of learning.

Communicating Acquired Scientific Knowledge

Engaging future science teachers in the inquiry process increases the likelihood they will teach using inquiry (Miller & Martin 2016; Seungoh & Fulton; 2017). For example, Nesmith et al. (2014) described a graduate class in which a science teacher educator posed questions about Newton's three laws of motion and asked the candidates to use whatever tools they had to test their ideas, gather data, and form conclusions. Throughout the process, the instructor asked probing questions, supported the learners by increasing their access to technologies, and formatively assessed their process and understanding throughout the activity.

At one point, the learners' wonderings focused on an inquiry of how an object impacting a bowl of water affected the form of the water. To engage in the inquiry, the learners first used a camera that could record the impact and then used software for viewing the video in slow motion and making increasingly detailed observations about the experiment. They then used the video to record data and draw conclusions (Nesmith et al., 2014).

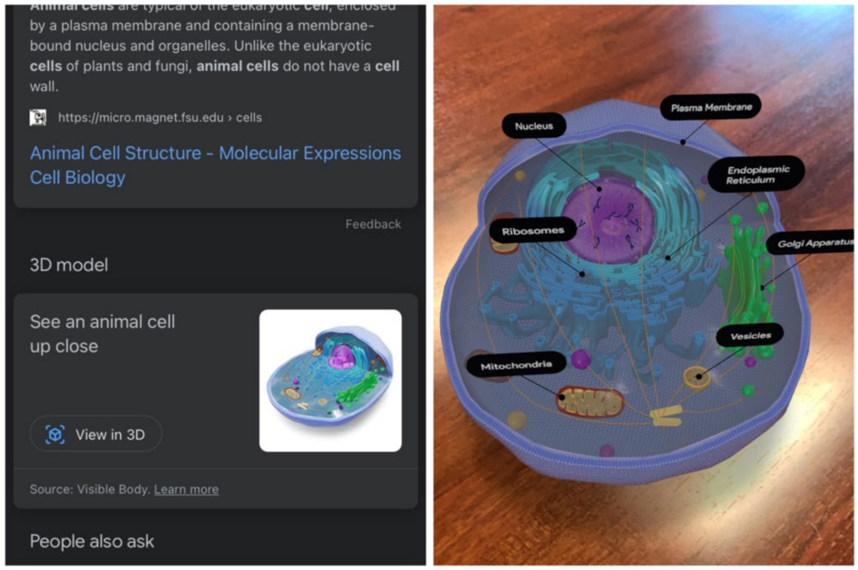
Throughout the inquiry-based project, the candidates made use of personal digital science notebooks to record data and observations and to organize digital artifacts that supported their inquiry. Digital notebooks offer several advantages: (a) drawing, (b) audio-recording, (c) video-recording observations, experimentation or certain phenomenon, (d) adding digital photos to enhance and complement content learning, (e) annotating on a page or even labeling drawings, and (f) dictating alongside data collection with probeware (Martin & Miller, 2016; Seungoh & Fulton; 2017). Furthermore, a digital notebook (Ferguson, 2021) provides several options not only to document phenomena but also to collaborate with peers. Science teacher educators who model the use of such notebooks provide their future science teachers with valuable tools that both facilitate data collection in these hands-on experiential opportunities and afford students novel ways to communicate their findings with the technology.

Digital science notebooks are an example of interactive amplification because the students use them interactively to collect data and information and not just consume information from them (i.e., viewing data that has already been collected). They represent amplification, as they provide an opportunity to leverage resources that a paper science notebook cannot provide (i.e., pictures, video, and sharing with peers). In our model, science teacher educators' use of digital notebooks would be used in the domain of communicating acquired scientific knowledge.

Catalyzing for Information Acquisition and New Understandings

Creatively transforming the learning experience for young science learners is made possible through emerging technologies like augmented reality (AR). AR has been adopted for learning and training situations including medical visualization (Barsom et al, 2016), maintenance and repair (Feiner et al., 1993), robot path planning (Ong et al., 2010), haptic devices (Hite et al., 2019), and entertainment (Donally, 2018). Likewise, AR applications have proliferated on mobile devices. Many of these tools increase accessibility of information and provide learners with powerful visualizations of science content (see Figure 2).

Figure 2
Google AR Screenshot of an Animal Cell



AR can transform learning for science teacher candidates only when teacher educators use AR tools for creation in addition to consumption. In a methods course, AR can be used to project simulations or visualizations of scientific concepts. One example of science teacher candidates learning about teaching astronomy to fourth graders indicates how this would work. The teacher educator introduces the iPad applications Keynote and AR MAKR to the teacher candidates and asks the candidates to design an accurate representation of our solar system to be displayed in the classroom — again, through AR. Candidates are guided in how to create and manipulate objects through AR MAKR. This same process can be replicated in the fourth-grade classroom, as Figure 2 illustrates.

This activity represents creative transformation, as the students are asked to create a model for display in the AR environment. It is transformative, as the final AR product represents a scientific visualization that is entirely different from what is possible in an analogous analog environment. In our model, this application of technology by a teacher educator would be classified in the domain catalyzing for information acquisition and new understandings.

Secondary Science Teacher Preparation

Supporting the Navigation and Process of Learning

Almost all teacher educators now use a LMS provided by their university. The basic features of this system adopt technology as a *passive replacement* of traditional classroom functions to support students' navigation and location of relevant information for learning. For example, instead of a teacher educator writing an assignment on a board at the front of the class, the assignment is now posted in the LMS for students to access. Additionally, students may turn in an electronic copy of the assignment within the LMS, eliminating the need for a basket on a classroom table to collect papers. An LMS thus increases convenience and access for both instructors and students.

It is important for science teacher educators to expose teacher candidates to the instructor side of the LMS that students may not normally see. While teacher candidates may not have access to the same LMS when they are in their secondary classroom, they will have access to either a version purchased by their school or some free versions they can find online. While systems such as Canvas and Blackboard are prevalent at the collegiate level, analogous systems such as Schoology and Google Classroom are often available in K-12 schools. Teacher candidates should be ready to use the most basic features of an LMS in their teaching.

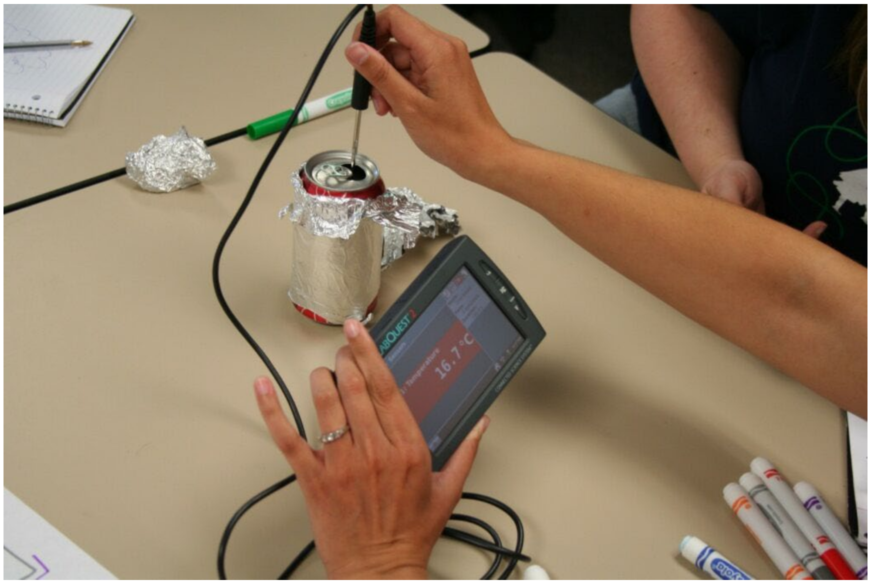
The use of an LMS in this case is an example of passive replacement, as the students are not asked to interact with the system but instead use it to consume information about the course. It replaces the traditional methods of sharing course information in the classroom and makes this information accessible at all times. In our domains, this is an example of supporting the navigation and process of learning.

Catalyzing the Acquisition of Information and New Understandings

Science teacher educators must also prepare teacher candidates to use the technology that is most available to students. For secondary students, this often comes in the form of a mobile device, such as a tablet or smartphone, that can allow for the interactive amplification of the learning activity. Many secondary schools have now adopted policies that allow students to use personal mobile devices for educational purposes during the school day. Other secondary schools provide students with mobile technology for educational use. Either way, mobile devices are powerful and easy to use and can be cultivated to teach science content.

Today, many of these mobile devices feature an array of data sensors that can collect highly accurate information from the user's environment in real time. The most ubiquitous sensor on these devices is the camera, which can record both still images and video at high resolution. An example of a mobile app that leverages this tool for scientific data collection is Vernier Video Physics (https://www.vernier.com/physics/vernier-video-analysis/), which allows the student to record a video of a moving object and extract position, velocity, and acceleration data from that video. An example is shown in Figure 3.

Figure 3
Example of Vernier in Lab



Science teacher educators must embrace the opportunity to expose teacher candidates to and train them in these applications of mobile technology, ensuring that teacher candidates appreciate both its affordances and the limitations. It will also build their confidence to equip their own future students with the technology to help them learn science.

The use of video analysis is an example of interactive amplification, as the students interact with the device. They upload the video, set the parameters, and enter data points. This amplifies the experience of analyzing an event, as it is difficult to obtain similar information in real time by other means. In our model, this application of technology by a teacher educator would be in the domain of catalyzing the acquisition of information and new understandings.

Communicating Scientific Knowledge and Understanding

Technology integration that is transformative in nature provides students unique opportunities for learning that were not previously possible without the technology under consideration. Instead of simply replacing or even amplifying an existing instructional practice, transformative technology integration provides a learning experience that could not have otherwise been possible via alternative or low-tech means (Kimmons et al., 2020).

One example of a science activity that features creative transformation through technology can be found in socio-environmental science investigations (SESIs; http://stelar.edc.org/projects/22423/curricula/socio-environmental-science-investigations). These investigations are conducted by secondary science students and focus on local problems that can be explored through fieldwork, data collection, and collaboration. In one example, students use mobile devices to gather novel georeferenced data from beyond the school (i.e., a neighborhood or other local area), collate the data into a shareable digital data set, and analyze the data using GIS technology (Environmental Literacy and Inquiry Working Group, 2020). Investigations may include the topics of tree identification, zoning areas, and urban heat islands that may be occurring in their own local areas. The information, analysis, and conclusions that students reach are novel, student driven, and otherwise impossible in any other context or without the use of technology.

Science teacher educators can showcase these examples of creative and transformative technology use with their teacher candidates to demonstrate that such activities are both feasible and productive. This kind of technology use is also a natural complement to inquiry-oriented lessons, where students are expected to exercise a high level of agency when conducting the scientific activity. It is crucial for the science teacher educator to demonstrate how technology can afford teacher candidates the opportunity to reach this high level of student inquiry.

SESIs represent a creative transformational use of technology, as the students create the layers of data to overlay on the maps. This activity is transformational, as only through the use of technology can students add and remove layers of data that are georeferenced in a manner that can be created quickly and analyzed efficiently. In our model, a teacher educator's use of SESIs would be in the domain of communicating acquired scientific knowledge and understanding.

Conclusions Regarding Technology Integration in Science Teacher Preparation

Student learning in science can be meaningfully supported by the thoughtful integration of technology, provided that such integration complements an intentional pedagogical approach (Annetta et al., 2007; Weintrop et al., 2016). Educational technology helps teacher educators reimagine how to teach and enhances opportunities in education preparation programs. Teacher educators can reach teacher candidates and promote their effectiveness as future professional educators by modeling how to best use meaningful technology. Technology-infused teaching allows students to develop important skills, practices, and literacies that connect to life outside the classroom (Kljun et al., 2020).

The domains for the use of technology by teacher educators suggested in this work are powerful and can help identify ways to best use educational technology. Science teacher preparation programs should infuse technology throughout science teacher preparation coursework with fidelity toward science as a discipline. This approach will provide teacher candidates with educational experiences and applicable critical thinking skills that support learner development.

Perhaps the most fundamental reason for introducing an integrated approach in teacher preparation programs is to provide teacher candidates the opportunities to learn to apply education technology tools, skills, and abilities in teaching science disciplines that will help them in the future. From an educational stance, an integrated approach presents the opportunity for future educators to broaden their range of pedagogical skills by incorporating technology across all grade levels and science disciplines.

Teacher educators can promote this integrated approach by matching objectives, teaching strategies, and technology to their context to support future science teachers' own scientific inquiry. Using digital technologies also requires explicit articulation of the affordances and limitations of technologies, and we encourage teacher educators to explore these aspects to support future teacher's adoption of digital technologies that fit their context. The explicit illustrations provided in this article of ways chosen technologies support learning and teaching of scientific content in elementary and secondary science methods classes exemplify the essential activities preservice teachers need to experience so they may effectively integrate science in their future practice. Finally, science teacher educators should encourage the enactment and practice of technology-integrated strategies throughout coursework, including methods courses and field experiences.

Successfully integrating science teacher methods and technology will require collaboration and professional development. Technology-infused education preparation programs will require a considerable amount of forethought, planning, allocation of resources, and support during implementation. By definition, a technology-infused approach suggests there could be an increase in instructional strategies in the pedagogical tool box of teacher educators.

Instructional strategies will still incorporate tried and true science pedagogies such as project-based learning, guided inquiry, research investigations, and simulations – but with the addition of technology. This change in mindset is a necessary response to the changing landscape of education and the reform needed for educators to thrive no matter the instructional context. We envision the science teacher preparation field will continuously and cumulatively grow and bring scholarly and relevant ways to engage students in science with technology.

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