Promising Practices: A Literature Review of Technology Use by Underserved Students

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Summary of Key Findings

How can technologies and digital learning experiences be used to support underserved, under-resourced, and underprepared students? This report summarizes research findings about the conditions and practices that support positive outcomes of technology use for these student populations. Related to technology specifically, we find that:

1. **Underserved students benefit from opportunities to learn that include one-to-one access to devices.** One-to-one access refers to environments where there is one device available for each student in the learning environment. One-to-one learning environments vary widely in terms of the time spent using devices, the overall availability of devices (e.g., whether the students can bring them home), and the quality of the instructional materials accessed with the device. While this is true, the literature in this review supports the notion that students may benefit from opportunities to learn when there is at least one device per student.

2. **High-speed Internet access is needed to prevent user issues when implementing digital learning.** Digital learning often requires Internet access, and this need is growing with the proliferation of online audio and video resources. Research indicates that fast and reliable Internet connectivity is important for digital learning.

3. **Underserved students benefit from technology interactions designed to promote high levels of interactivity and emphasize discovery.** The design of technology tools allows for different types of interactions between the learner and the technology. In the literature, designs that support interactive and constructivist activities were demonstrated to support learning by minority, low-SES, and other underserved students, specifically those highly interactive activities that allow students to craft their own understanding of complex content. These include tools that provide students with **opportunities to represent thinking in multiple forms (e.g., text, numbers, symbols, graphs, charts, pictures, and video)**.

4. **Successful digital learning environments are characterized by the right blend of teachers and technology.** The role of the teacher in blended and fully online learning environments varies widely. One study in the review reports specific findings about digitally mediated learning by underserved secondary students with varying levels of teacher support. The study highlights student satisfaction in environments characterized by higher levels of teacher support for student

learning and opportunities for interactions among students. The authors also recommend the use of real-time digital feedback in digital learning environments. A meta-analysis of research on blended learning across a range of education levels found that **purely online learning led to only slightly differing results than face-to-face learning, but students in blended learning environments performed significantly better as compared to those in face-to-face conditions that do not include digitally mediated instruction**.

With regard to the conditions and practices that support learning by this population, we find that:

1. **Underserved students benefit from learning activities that focus on the development of higher order thinking skills** (such as problem-solving, making inferences, analyzing, and synthesizing) and 21st century skills. These should be prioritized over activities targeted at basic skill development (such as memorizing facts and applying rules). For example, research indicates that simulations and games with certain foci such as higher order thinking skills, development of 21st century skills, or strengthening brain function are beneficial for minority, low-SES, and other underserved students. These findings are consistent with the literature on technology for learning by the general population of K–12 students, which also shows that digital learning supporting problem-solving and other higher order thinking skills has more positive effects than digital learning opportunities that emphasize the development of basic skills.

2. **Underserved students benefit from learning activities that draw on culture and community,** specifically activities that integrate culturally relevant practices, foster student development of expertise, and highlight this expertise by providing opportunities for students to share their knowledge and skills with authentic audiences. Digital learning activities that were connected to the learners' cultures and communities were evident in a number of studies. This research indicates that the combination of cultural relevance, community, and authentic audience led to improvement in students' writing skills, motivation, and interest in school-related activities.

3. **Underserved students benefit from learning activities that provide them with opportunities to drive their own learning. This includes activities that allow students to become content creators.** For instance, students are involved in the learning process when they are provided with choices about which digital task to complete, how knowledge will be demonstrated via technology, or the ways the

technology will be used. This type of student agency was featured in three different studies and was manifested in a variety of ways. It included the use of technology to provide students with a choice of instructional materials and the use of technology to allow students to become active agents in their learning (e.g., making decisions about how a task was done). Activities that involve students as content producers also show links to promising positive outcomes for students. In a number of studies, minority, low-SES, and other underserved students were engaged in content creation projects, and in these activities students demonstrated improved engagement, self-efficacy, attitude toward school, and skill development.

Introduction

For many years, educators, researchers, and policy makers looking for strategies to close the achievement gap and improve student learning have sought solutions involving new uses of technology, especially for students considered to be at risk of failing. However, the results of various technology initiatives for these students have been mixed. As often as not, the introduction of technology into classrooms has failed to achieve the grand expectations proponents anticipated. The educational landscape is replete with stories and studies about how specific student populations were unable to benefit from particular innovations that feature the use of technology for teaching and learning.

However, there are successes among these efforts that when taken together reveal some promising practices for technology use by underserved students. This report, based on a review of more than 50 studies and reports published between 2003 and 2013, describes these approaches—particularly as they apply to students considered to be at risk of failing courses and exit examinations or dropping out. Broadly, our focus includes underserved, under-resourced, and underprepared students who have been placed at risk by the organizations that serve them and societal structures in which they live. Specifically, we examine research reporting on students in grades 6-12 who have been labeled as minority, low-SES, low achieving, under-credited, or not on track to graduate. Moving forward, use of the term "underserved" in this report will refer specifically to students with one or more of these social markers. This is not intended to be a comprehensive definition of "underserved". Instead it is the operational lens used to delineate the scope of this review. With this focus, we seek to understand how technologies and digital learning experiences can be used to support the learning process for this subset of historically underserved student populations.

This population of interest includes more than 16 million U.S. students who live below the poverty line (DeNavas-Walt, Proctor, & Smith, 2013) and an additional 8 million who qualify for free or reduced price school lunch (Digest of Education Statistics, 2013a, p. 2). Altogether, these children in poverty now comprise 50% of our nation's public school students.

This population of interest also includes the nation's 23.8 million minority students, who account for nearly half of the school population, and many are underserved by their school systems. For example, nearly half of Hispanics, African Americans, and Native Americans do not graduate on time with their classmates (J. Watson & Gemin, 2008). Unfortunately, this is not unusual: more than 1 million U.S. high school students drop out each year, an average of one student every 29 seconds (J. Watson & Gemin, 2008). Studies show that on nearly every indicator of educational access—school funding, qualified teachers, high-quality curriculum, books, materials, and computers—low-income students and students of color have less access than White and affluent students (Darling-Hammond, 2010).

Research on technology, specifically in terms of reports on access and use, has begun to shift over the last decade. A series of national studies provides snapshots about the technology landscape over time (Gray, Thomas, & Lewis, 2010a; Gray, Thomas, & Lewis 2010b; Madden, Lenhart, Duggan, Cortesi, & Gasser, 2013). The two earlier studies give information about access in the classroom (Gray et al., 2010a; Gray et al., 2010b), while a more recent study looks at access more broadly, including students' technology use at home and via mobile devices (Madden et al., 2013). This exemplifies a shifting focus from access and infrastructure in schools to the "anytime/anywhere" computing that has become popular with the rise of mobile computing and steady increases in reliable high-speed Internet access. Research at the national level, however, has been slow to catch up, despite the rapid advances that characterize our technology-rich society. For example, when this review was conducted in 2014, the most recent relevant national report about in-school technology use was from 2009, one year before the iPad was introduced, and only 3% of the studies included in this review focused exclusively on mobile technology. Given the lag between research and publication and frequent releases of improved hardware and software, it is difficult to garner a clear and up-to-date picture of technology in U.S. schools today. This caveat is particularly relevant to a review of the literature, the approach we used in this study. The existing national research does, however, point to trends that are consistent with the notion of a persistent digital divide. Specifically, these studies reveal a disparity in access to computers and their frequency of use between low- and high- poverty schools (Gray et al., 2010a; Gray et al., 2010b).

Outside of school, additional inequitable access is also evident. Two surveys conducted in 2012 reveal disparities in hardware ownership and Internet access across socioeconomic levels and racial/ethnic minorities (Madden et al., 2013; Purcell, Heaps, Buchanan, & Friedrich, 2013). Both low-SES teens and racial/ethnic minorities are less likely to use the Internet than their more affluent and white peers. Additionally, racial and ethnic minorities, especially Hispanics, are less likely to own a computer, and low-SES youth are less likely to own a tablet. This is noteworthy given that students with computers in their homes have higher GPAs, and are more likely to graduate, less likely to be suspended, and less likely to engage in criminal activity than those without computers in their homes (Beltran, Das, & Fairlie, 2006). Although there is not a difference across SES or race in terms of smartphone ownership, African Americans are more likely than whites or Hispanics to use their mobile device as their primary Internet touch point, which has implications for the ways the Internet can be used outside of school. Using the Internet on a smartphone limits an individual's capacity to engage in content creation, content editing/remixing, deep online research, substantial word processing projects, and a number of other formal and informal learning activities. On the flip side, a complete lack of mobile Internet use precludes the type of anytime/anywhere involvement that is crucial to youth engagement with the wide variety of digital learning tools that rely on just-in-time online access, real-time digital interactions, and up-to-date information sharing.

The importance of reliable high-speed Internet access is increasing as technology evolves and inequitable broadband access patterns have been flagged as a national priority. In June 2013, in response to the fact that only 20% of U.S. students had access to high-speed Internet connectivity, President Obama announced the ConnectED initiative, presenting the goal of getting 99% of U.S. students connected by 2018 (Obama, 2013). Advances toward this goal and others like it necessitate rigorous updates to school infrastructure and technology access nationwide. While such enhancements might begin to address the digital divide, increased access alone is not sufficient for improving educational outcomes for underserved students. Once access is granted, we must consider how technology can be used to support learning by those who need it the most.

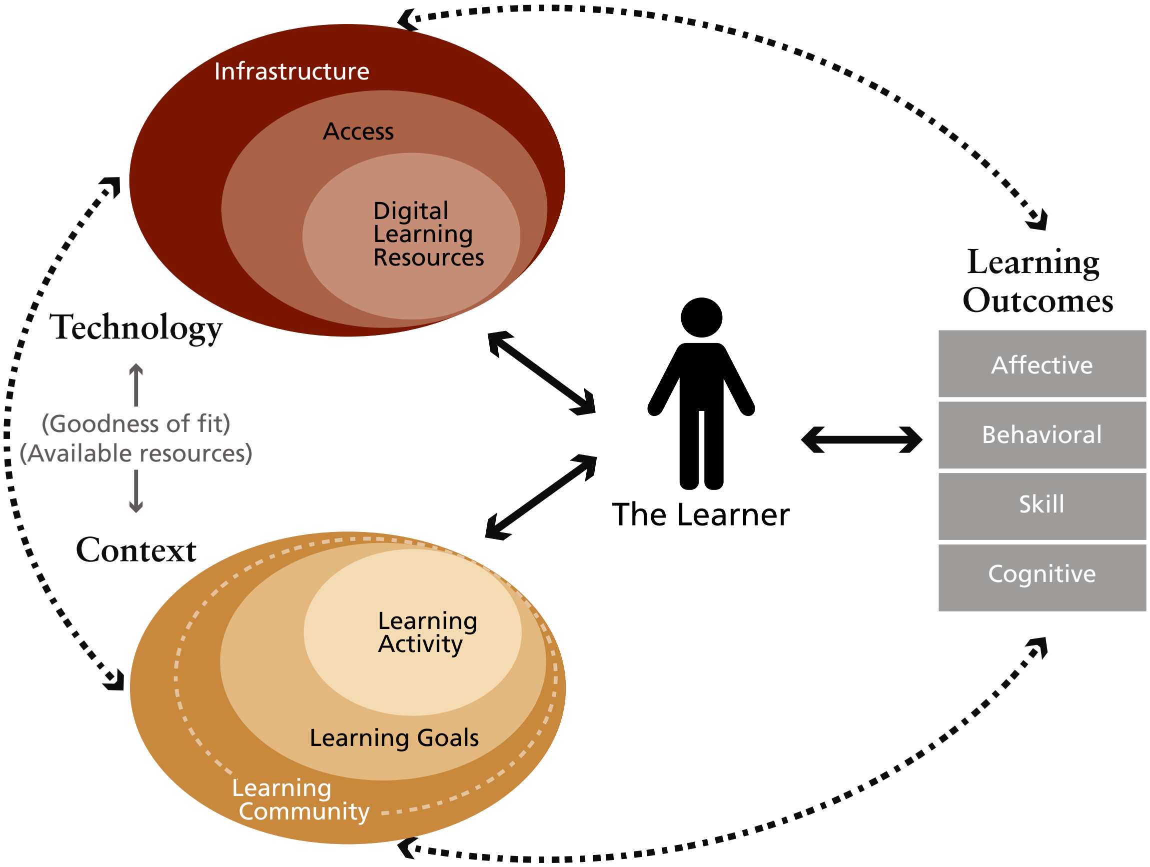
To further develop our understanding of how digital tools can be used to support underserved, under-resourced, and underprepared students, we conducted a comprehensive literature review, taking into account more than 50 studies, white papers, reports, and reviews primarily published between 2003 and 2013. We introduce and describe a Digital Learning Ecosystem developed during the review process as well as the key findings and recommendations for practice emerging from this review.

Digital Learning Ecosystem

The Digital Learning Ecosystem (see Exhibit 1, next page) was developed in our review process, and is based on an in-depth analysis of 23 highly relevant reports and reviews that synthesize the findings from over 2,000 empirical articles about technology for learning[1]. From these, over 450 evidence-based claims were excerpted and organized thematically as a way to see beyond individual studies and holistically visualize the variables that influence digital learning and their relationship to one another. The resulting framework reveals the complexity of the Digital Learning Ecosystem and illustrates that learning outcomes are the result of interactions among numerous variables within a complex system. No single variable can ensure a desired outcome, as all the components within the ecosystem are mutually interdependent. The research suggests that taken as a collection, each component must be evaluated in terms of its alignment to all other variables if sound decisions are to be made about the use of technology for learning. In the coming section, each component of the Digital Learning Ecosystem is introduced. In the subsequent section, this ecosystem is used to frame the findings from our review of the last decade of empirical work about underserved students learning with technology.

The ecosystem is designed with the learners at the center. Whether we are talking about retirees using Massive Open Online Courses or ninth graders using games and

EXHIBIT 1. THE DIGITAL LEARNING ECOSYSTEM



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simulations to learn Algebra I, characteristics of the learner have direct implications on the way students engage with digital learning tools. Additionally, what learners bring to their learning environment—such as their previous experiences, content knowledge, skill level, technological literacy, and social emotional state—plays some part in mediating the outcome of a learning activity. These learning outcomes are often narrowly conceived in terms of academic achievement, but our analyses have indicated that this idea is somewhat shallow. Instead of solely academic outcomes, research indicates that learners' experience results fall across four domains: affective, behavioral, skill-based, and cognitive. Our review points to two major spheres of influence that shape the learners' experience and outcomes: the technology sphere and the learning context.

In the technology sphere, the most influential components can be characterized in terms of infrastructure, access, and the specific features of a digital tool. Infrastructure refers to the "back end" of the technology setup. This includes categories such as bandwidth, servers, storage, and data hosting models. Access refers to the hardware used in the learning environment but also includes the model for access, which describes the organization of the learners and a particular device as well as the time, place, and frequency of access to this device. In schools, common models for access include one-to-one stationary computer labs, mobile computer labs, and bring your own device (BYOD). At-home models for access include the ownership or sharing of computers, tablets, and smartphones, and whether or not these are connected to the Internet. Youth also have access to technology at various points in the community beyond home or school. Infrastructure and access are closely related, and each provides a set of enabling (or disabling) circumstances surrounding the use of technology in service of various learning outcomes. Each also plays a part in either limiting or extending the success of a particular digital learning resource. In this report, digital learning resources are described in terms of the platform or application being used and the specific features of that digital tool. These features influence the way content is presented, stored, and revisited, as well as whether and how information is manipulated and shared. The features of a digital tool make visible a wide variety of design specifications that shape a learner's experience with a digital tool and thus influence the resulting outcome.

Considerations of infrastructure, access, and digital learning resources alone are not sufficient for drawing conclusions about the potential effectiveness of technology. The context for learning is equally relevant and thus constitutes the other major sphere of influence in the Digital Learning Ecosystem. Like the technology sphere, the context is also subdivided into three categories: the learning community, the goals and objectives for learning, and the actual activities that learners engage in as they are using the digital tools. Exhibit 2 delineates the aspects of the learning context at each of these levels as they commonly appear in the literature.

EXHIBIT 2. LEARNING CONTEXTS IN THE DIGITAL LEARNING ECOSYSTEM

Learning Community

Factors within **school/local communities**. For example:

- Approach to learning
- Pedagogical values
- Norms and cultures
- Parent involvement

Factors within **classroom communities**. For example:

- Grade level
- Teacher experience level
- Classroom management strategies

Learning Goals

Objectives for using technology:

- Mastery of basic skills
- Promote higher order skills
- Remediation of skills
- Promote technological literacies
- Promote skill development
- Influence learner behavior
- Make or build something
- Exploration of interests
- Pursuit of friendships

Learning Activity

Academic subject(s) or other content area

Interaction model(s):

- Content consumption
- Content creation
- Content sharing
- Interactive simulation/games

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The technology and the learning context interact to provide a unique set of conditions for learning. The characteristics of learners mediate their responses to these conditions and shape their engagement in the learning activity. Together, these variables constitute a distinct experience for each individual learner, and the experience in turn enables a wide variety of outcomes that come to be associated with the use of particular digital resources. This ecosystem is more evolved than the binary conceptions of technology for learning common at the end of the 20th century. The early years of the digital divide were characterized in terms of having or lacking access, and little information was collected or reported about the details of use. Even now, it is common for researchers to report on some but not all aspects of the Digital Learning Ecosystem presented here, and there is little explanation given for what is included and what is left out.

The major benefit of the ecosystem approach used here is that it makes clear the need to understand outcomes for learners with regards to the multiplicity of variables that impact both the learners' experiences and the potential outcomes associated with technology use. We cannot assume that the success of digital learning activity in one classroom will generalize to success in another classroom without also understanding details about the technology, the learning context, and the desired learning outcomes. For instance, Grimes and Warschauer (2008) studied one-to-one laptop implementation and observed different outcomes according to SES level. Rather than attributing this simply to the demographics of the student population, they looked more deeply at the learning context and determined that high- and mid-level SES schools frequently hired teachers with stated interest in science and technology, a factor that corresponded with extensive use of the laptops in the classroom. Teacher interest in technology, previous experience with digital tools, and technological literacy proved to be essential facets of the learning context, which was critical for understanding variation in learning outcomes associated with the use of technology. This is one of many elements within the ecosystem that could be overlooked in a simpler framework for examining educational technology.

In the remainder of this report, the ecosystem is used as a frame for presenting the findings from the literature about technology use and learning by the specific learner populations of interest (see Appendix A for methodological details including study selection and analysis). Each finding presented points to a specific variable in the Digital Learning Ecosystem, offering details from the literature on how it can be leveraged to best support learning outcomes for underserved students. **When considering these levers for change, remember that strong alignment among all the elements within the Digital Learning Ecosystem in a given context supersedes any of the specific practices listed below.** The potential for achieving the positive outcomes associated with these practices decreases when there is poor alignment between a given practice and the other elements within the ecosystem—and likewise increases when a practice is clearly aligned with the available technology, specified context, characteristics of the learners, and desired learning outcome.

Findings

Technology Sphere

The technology sphere refers to infrastructure, access, and features of the digital learning resources available to the learners. Several key recommendations within this sphere are presented below given the potential of each to set the stage for productive learning by underserved youth.

Underserved students benefit from opportunities to learn that include one-to-one access to devices. One-to-one access refers to environments where there is one device available for each student. There is wide variation within one-to-one environments, including the time spent using devices, the overall availability of devices (e.g. , whether the students can bring them home), and the quality of the instructional materials used on the device. While this variation can be profoundly influential, the literature supports the notion that students often benefit from opportunities to learn when there is at least one device per student (Grimes & Warschauer, 2008; Maninger, 2006; Rizhaupt, Higgins, & Allred, 2010; Rizhaupt, Higgins, & Allred, 2011; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2009). For example, Grimes and Warschauer (2008) studied "the implementation of a one-to-one laptop program in three diverse schools in California. The program was carried out in one largely Hispanic low socioeconomic junior high school, one largely Asian–American high-SES K–8 school, and the gifted program in a medium-SES elementary school" (p. 305). Their findings indicate that a majority of teachers found the laptops to be useful for learning by "at-risk" youth and that low-SES students demonstrated significantly higher gains in mathematics as compared to the high-SES students in the laptop program. Regardless of SES, the one-to-one laptop implementation increased students' likelihood to engage in the writing process, practice in-depth research skills, and develop multimedia skills through "interpretation…and production of knowledge" (p. 319).

High-speed Internet access is needed to prevent user issues when implementing digital learning. Digital learning often requires Internet access, and this need is growing with the proliferation of online audio and video resources. Kim and Lee (2011) found that underprivileged students participating in blended and online courses reported that a faster Internet connection would have improved their learning experiences. Grimes and Warschaeur (2008) found that when students were given one-to-one laptop access as well as access to the Internet at school, they made use of this at least several times per week: "We witnessed online information access by students for three main purposes: to provide background knowledge, to facilitate 'just in time' learning, and to support research projects" (p. 317). Fast and reliable Internet access allows teachers and students to support learning in real time.

Underserved students benefit from digital activities designed to promote high levels of interactivity and emphasize discovery. The design of technology tools allows for different types of interactions between the learner and the technology. In the literature, designs that support certain types of interactions repeatedly demonstrated support for learning by minorities, low-SES students, and other underserved students. Several design considerations that promote interactivity and exploration are presented below.

First, underserved students benefit from technology interactions designed to promote high levels of interactivity (Bos, 2007; Callow & Zammit, 2012; Elam, Donham, & Soloman, 2012; Figg & McCartney, 2010; Watson & Watson, 2011). The level of interactivity refers to the amount and type of interactions permitted between learners, technology, and content, where a high level is characterized by frequent opportunities to manipulate, examine, and create new content in a variety of forms. For example, in one study, students measure the heart rate of their peers during various activities and use this to generate and test hypotheses. In another, students used handheld GPS devices to participate in a scavenger hunt. Using interactive approaches such as these has been found in several studies to be successful in helping low-income students pass state competency tests (Bos, 2007) and master complex new materials (Hannafin & Foshay, 2008).

Second, underserved students benefit from technology interactions designed to emphasize discovery and exploration rather than direct instruction (Bos, 2007; Harness & Drossman, 2011). For instance, a design that includes features of technology that "generate fluency, [and allow students to] create and modify representational forms is used to develop the dimensionality of a quadratic function through exploration, problem solving, and through making and exploring virtual environments" (Bos, 2007, p. 356). Students who were allowed to explore the concept of quadratic functions in this study significantly outperformed those who learned via lecture and note-taking. In this example, students constructed understanding by working directly with graphs and tables. Afterward, they answered guided open response questions to help further develop their understanding of quadratic functions and checked this understanding through dialogue with other students (Bos, 2007). Experiential learning such as this allows students to develop their own understanding through exploration prior to direct instruction. This strategy is augmented when combined with built-in opportunities for students to synthesize and apply what they are learning, for example, by engaging in face-to-face or digitally mediated dialogue with peers and teachers, capturing emerging knowledge through written reflection, or completing other informal formative assessments.

Examples of high levels of interactivity and exploration include technology tools that allow the learner to engage with data and complex content, and represent thinking in multiple forms. Technology tools and their specific features and affordances structure the interactions students have as they engage in digital learning activities. Such features and affordances can be leveraged to provide learners with opportunities to engage productively with their peers or directly with content. In the literature, highly interactive tools that promote data analysis, engagement with complex content, and opportunities to convey understanding in multiple forms repeatedly demonstrated support for learning by underserved students. These are introduced and exemplified below.

First, underserved students benefit from learning with technology tools that allow the learner to engage in data collection and analysis (Bos, 2007; Elam et al., 2012; Grimes & Warschauer, 2008; Marino, 2009). In studying one-to-one laptop implementation, Grimes and Warschauer (2008) observed the following:

> Laptops also allowed students to better gather and analyze their own data as part of the research process. This principally took place in science and mathematics instruction, as students analyzed data with spreadsheets. The most interesting example we witnessed of data collection and analysis was at Flower, which had purchased a set of scientific probes that can be attached to the laptops for gathering and uploading of data related to temperature, voltage, light, force, motion, and chemical composition. In one lesson we observed, students worked in groups to measure each other's heart rates in various states (sitting, standing, jumping) and upload the data to computers where it was plotted into graphs. In the process, they developed and tested hypotheses about the affect of various combinations of activity and rest on heart rate. (p. 318)

In this study, 82% of teachers in low-, middle-, and high-SES schools found that the laptops enabled them to "get more involved with in-depth research" (p. 318). In addition to engaging in data collection and analysis, the low-SES students in the laptop implementation study showed significantly higher gains in math than those in the high-SES schools.

In another study, Elam et al. (2012) invited disadvantaged teens from 10 rural and financially disadvantaged school districts to participate in a science-focused summer camp. Several of the camp activities focused on the use of data, including a campus-wide scavenger hunt using GPS and a kite design project: "Using basic engineering design principles, simulation software, and fundamentals of aerodynamics, student teams designed, built, and tested various kite designs" (pg. 38). In this study, students showed improved attitudes towards science and an increase in science career interest.

Second, underserved students benefit from learning with technology tools that allow the learner to engage with multiple methods for accessing and understanding complex conceptual content. Technology that allows students to manipulate simulations and interactive models can support the development of understanding difficult concepts (Bos, 2007; Bottge, Rueda, & Skivington, 2006; Samsonov, Pedersen, & Hill, 2006). For instance, Bos (2007) found that low-achieving students using an interactive instructional environment to study quadratic functions had significantly greater mathematical achievement than those in a control group who learned via traditional lecture, note-taking, and the drill and practice approach. The technology environment enabled students to construct their own understandings of quadratic functions by manipulating graphs and tables, answering open response questions, and engaging in dialogue about their findings. Bottge et al. (2006) also reported significant results in mathematics achievement resulting from video-based instruction modules that provided students with access to multiple means for understanding the complex content. Within the video environment, annotations were used to scaffold students towards identifying important elements in the problem. For example:

> The eight-minute video problem in *Fraction of the Cost* was developed locally and stars three middle school students who decide to build a skateboard ramp. To answer the subproblems in the video, students needed to calculate percent of money in a savings account and sales tax on a purchase. They also had to read a tape measure, convert feet to inches, decipher building plans, construct a table of materials, compute mixed fractions, estimate and compute combinations, and calculate total cost of building the ramp. Several learning tools on the CD-ROM helped students understand concepts in the overall problem. For example, one module showed a three-dimensional ramp that students could rotate to see all sides. The 2 x 4s (i.e., dimension lumber) used in building the ramp were color- coded to enable students to see more clearly which lengths corresponded to which parts of the schematic drawing. In another module, students could build the ramp by dragging lengths of 2 x 4s out of a stack of lumber and attaching them in the correct way. (Bottge et al., 2006, p. 398)

In both examples, students interact with digital content that was designed to enrich their understanding of complex content. In the first example, students manipulated graphs and tables then constructed their understanding through writing and dialogue. In the second example, students engaged with video content that included instructional supports, interacted with 3-D digital models, and applied their understanding by building a product in the digital environment. These are two examples of the ways that technology can be utilized to provide multiple methods for learners to grasp traditionally difficult concepts.

Third, underserved students benefit from learning with technology tools that allow the learner to engage with content from a variety of sources and represent thinking in multiple forms. Technology should enable students to communicate with one another, grapple with content, and demonstrate their understanding in a variety of ways (Bos, 2007; Callow & Zammit, 2012; Hall & Damico, 2007; Marino, 2009; Watson & Watson, 2011). While similar to the recommendation above that focuses on the representations of complex content provided within a digital environment, this recommendation is broader in that it encompasses the presentation of content from a variety of sources within and between digital environments. It also addresses the means for making sense of content and the creation of new content by students. Ideally, technology should provide multiple avenues for each. For example, students should not merely read about a new science concept in a digital textbook. They should read, highlight, and annotate the text; share these annotations; and then explore the concept with relevant simulations, watch videos, participate in digital discussions with experts, search for and analyze additional sources of information about the concept, and construct their own original content to convey their developing understanding about the subject. Additionally, the type of content students create should not be limited to a textual description but instead should allow for the integration of text, audio, and video as methods for recording and sharing their understanding. Callow and Zammit (2012) present multiple case studies illustrating uses of technology that present content in multiple forms. In one case, the teacher presents an excerpt from the book the class is reading on the Smart Board. The excerpt is enriched with "hyperlinks to visual images, maps, word definitions and pronouns, personalised with students' names. The students used highlighters to feature key vocabulary on print [versions of the excerpt]" (p. 47). Through the use of technology, students are seeing content in a myriad of forms as it comes alive with maps, videos, definitions, and more. This and the examples above provide some detail about the ways in which highly interactive technologies can be used to enrich learning experiences by providing students with opportunities to engage with data, interrogate complex content in a variety of forms, explore content from multiple perspectives by drawing on a variety of sources, and demonstrate new understanding by creating original content.

Digital learning environments, characterized by significant levels of teacher support, content practice with real-time digital feedback, and opportunities for social interactions among students, show promise for underserved students. Kim and Lee (2011) produced the only study in this review to look at the conditions under which there was a comparison between different levels of teacher support in digital learning environments. In this multiregional study involving 1,943 Korean students (of whom 915 were identified as underprivileged) students engaged in online courses using Flash animation and video learning resources. Students progressed through learning sessions by completing online tasks individually and engaging in group discussions. In this study, there were two different types of digital learning: online learning supported by a homeroom teacher (blended condition), and students engaging in self study without the help of any teachers (online condition).

Kim and Lee (2011) found that "teacher assistance [present in the blended condition but not the fully online condition] seems to be mandatory for the online learning of underprivileged students" (p. 2403). Students illustrated high levels of satisfaction in the blended learning condition because of the real-time support and encouragement they received from homeroom teachers, an element not available in the fully online condition. When students were asked to select the area where they experienced the most personal development, there were several advantages for those who experienced the blended context. Learners who worked with teachers alongside their online experience were much more likely to say that they developed an interest in the subject and increased their academic standing, while learners who did all of their work online were much more likely to say that they experienced no change in their learning (that is, that digital learning was ineffective). Additionally, the students in the online condition reported satisfaction associated with opportunities for interactions among learners. Finally, real-time digital feedback was identified as a component necessary for successful digital learning experiences (Kim & Lee, 2011). However, little information is given about the nature of this feedback or how it looks[2]. Because this study was conducted in Korea and learner characteristics there may vary from those in the United States, this research does not provide a promise of success but instead warrants further investigation into various digital learning models and the associated levels of teacher support that are used in U.S. elementary and secondary schools.

Some additional insight can be garnered from a meta-analysis of 45 studies of blended learning across a range of education levels. Means, Toyama, Murphy, and Bakia (2013) found that purely online learning led to only slightly differing results than face-to-face learning, but students in blended learning environments performed significantly better as compared to those in face-to-face conditions. As deeper analysis reveals, "Studies using blended learning also tended to involve additional learning time, instructional resources, and course elements that encourage interactions among learners. This confounding leaves open the possibility that one or all of these other practice variables contributed to the particularly positive outcomes for blended learning" (Means et al., 2013, p. 2). Here again, the findings point to potential design considerations including the provision of ample time and abundant resources as well as an echoing of Kim and Lee's (2011) recommendation to include opportunities for peer interaction. These findings also reinforce the need for future research in elementary and secondary schools to shed light on the models that mobilize the right blend of teachers and technology and identify the most influential features of successful blended learning tools.

Learning Context Sphere

The context sphere consists of the learning community, the learning goals, and the learning activity. While there is some overlap between the digital resources considered in the previous section and the learning activity presented in this sphere, there is a distinction. Discussion of the digital resources in the technology sphere is related to the specific design of the technology, while the learning activity has more to do with the choices about using technology to meet certain lesson objectives and goals within a learning environment. Within this sphere, three major recommendations were identified that show promise for stimulating active participation in effective digital learning activities for underserved youth.

Underserved students benefit from learning activities that focus on the development of higher order thinking skills (such as problem-solving, making inferences, analyzing, and synthesizing) and 21st century skills. These should be prioritized over activities targeted at basic skill development (such as memorizing facts and applying rules). Consistent with the literature on technology for learning by the general population of all K–12 students, the literature regarding underserved students reveals that digital learning supporting problem-solving and other higher order thinking skills has more positive effects than digital learning opportunities that emphasize the development of basic skills (Barley, Lauer, Arens, Apthorp, Englert, Snow, & Akiba, 2002; Bos, 2007; Ringstaff & Kelley, 2002; Wenglinsky, 1998). Warschauer and Matuchniak (2010) conducted a literature review about the equitable use of and access to technology by various learner populations. The following excerpt describes one finding in support of this recommendation:

> the drill and practice activities favored in low-SES schools tend to be ineffective, whereas the uses of technology disproportionately used in high-SES schools achieve positive results. The best evidence of this discrepancy comes from Wenglinsky (2005), who analyzed data from the NAEP in 1996, 1998, and 2000. Overall, Wenglinsky found a consistently negative interaction between frequency of technology use and test score outcomes in mathematics (at both the fourth and eighth grade), science (at both the fourth and eighth grade), and reading (at the eighth grade; see Table 10). This appears to be because of the negative effects of drill and practice activities that are used predominately with low-SES students. In contrast, the more constructivist educational technology activities typically used with high-SES students were correlated with higher test score outcomes…For example, in mathematics, Wenglinsky found that the use of simulations/ applications in eighth grade and games in the fourth grade positively affected test scores, whereas drill and practice at the eighth grade negatively affected the scores. In science, games (fourth grade), word processing (fourth grade), simulations (fourth and eighth grade) and data analysis (fourth grade) all positively affected test scores. And in eighth grade reading, use of computers for writing activities positively affected test scores, but use of computers for grammar/punctuation or for reading activities (which usually involve drill or tutorials) negatively affected test scores[.] (Warschauer & Matuchniak, 2010, p. 205)

Warschauer and Matuchniak (2010) utilize standardized test scores as evidence to support the idea of prioritizing digital learning opportunities that focus on higher order thinking over those that focus on basic skill development. Another instance of this in the literature comes from a study of 48 "at-risk" high school mathematics students in Texas. In this experiment, students spent 55 minutes per day, working through six lessons that followed the cycle: "engage, explore, explain, and elaborate" (p. 356). Through this cycle, students utilized simulations to manipulate information on interactive graphs and tables. They followed an exploration and were prompted to explain and elaborate on certain phenomena they observed. Students who engaged in this intervention outscored those learning in more traditional forms. The authors conclude that "results are deeply embedded in the core of the learning process and the necessity to create an environment that involves all students in high level thinking skills and to promote problem solving versus a more drill-practice approach"(Bos, 2007, p. 366).

These examples point to the utility of simulations and digital games for the development of higher order skills. The literature also indicates that these are useful for promoting 21st century thinking skills and brain development (for example, working memory and vocabulary development). Specifically, educational games have been linked to skill and concept development for underserved students (Alloway, 2012; Rizhaupt et al., 2010; Rizhaupt et al., 2011). Ritzhaupt, Higgins, and Allred found that students who played single and multiplayer games demonstrated an increase in motivation, interest, and self-efficacy (and potentially academic achievement). Others have noted the importance of using digital learning environments (such as games and simulations) with features that are appropriate for the students' prior knowledge and skill level. For instance, Marino (2009) found that struggling readers using the interactive digital program *Alien Rescue* benefited far less than proficient readers when using the tools designed for generating hypotheses. Because this feature was not a good fit for this population, the authors recommend selecting digital learning experiences that support cognitive processes and student access of "out of reach" activities.

Alloway's (2012) research shows that when there is a good alignment between the learner and the features of the learning activity, there is increased potential benefit for the students. The study illustrates that students utilizing training games at regular intervals can strengthen and enhance a variety of cognitive capacities, including working memory, information processing, vocabulary, and cognitive flexibility. Fifteen struggling high school students used an online program called *Jungle Memory*, made up of three games. Each provided opportunities for brain training, for instance:

> In Game 1, letters and words appeared on a 4x4 grid. The working memory component was to remember the location of the target stimuli within a set time period. In Game 2, a letter appeared on the screen with a red dot on it. The letter may also be rotated. The working memory component was [when students] had to identify a letter orientation (processing) and remember the location of a dot

> (memory). In the final game, the student was shown math problems of increasing difficulty and had to solve it (processing component). They then had to recall the solutions in the correct sequence (memory). (Alloway, 2012, p. 200).

Findings from this study indicated increases in working memory, vocabulary, and mathematics achievement for the students who used the game but not for students in the control group. Thus our review of the literature indicates that simulations and games may be considered valuable resources for the development of higher order thinking skills and 21st century skills, particularly if there is a strong alignment between the strengths, interests, and needs of the learner and the features of the learning activity.

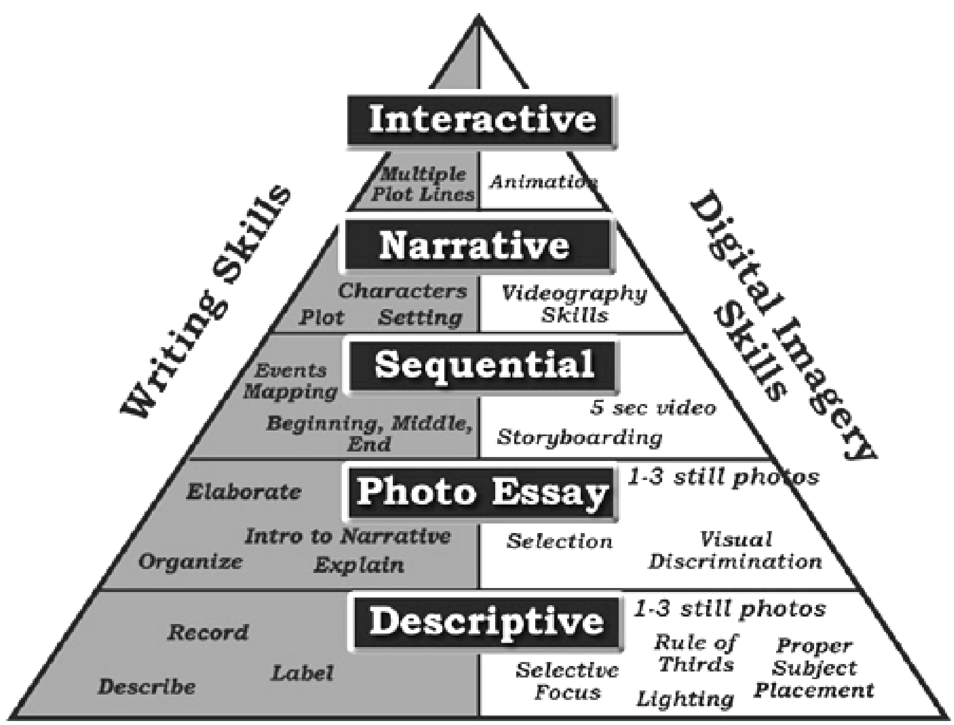
Underserved students benefit from learning activities that draw on culture and community, specifically activities that integrate culturally relevant practices, foster student development of expertise, and highlight this expertise by providing opportunities for students to share their knowledge and skills with authentic audiences. Digital learning activities that were connected to the learners' cultures and communities were more successful than those that were not culturally relevant. One form of cultural relevance was observed when students engaged family and community members in authentic content creation tasks such as creating a family movie (Figg & McCartney, 2010). Another form of cultural relevance was seen when Hall and Damico (2007) provided African American 10th, 11th, and 12th graders with interest-driven opportunities to create representations of their thinking about local social justice issues, prioritizing cultural relevance by encouraging students to make use of language that they were usually asked to suppress but is common within their communities.

Meaningful activities foregrounding culture and community were observed with respect to authentic audience, opportunities for communication, and the development of student expertise. In one study, peers, family, and community members were mobilized to provide students with an authentic audience for sharing multimodal creations. Parents enjoyed authentic opportunities to communicate with their children about learning (Figg & McCartney, 2010). Additionally, authenticity was created through opportunities that honored students' roles as experts, for example, the provision of opportunities for the teacher to learn from the students and opportunities for parents to see children as experts (Figg & McCartney, 2010).

This project conducted by Figg & McCartney (2010) was culturally relevant because the students were asked to "draw upon oral or biographical family history," making them each experts in their own topic (p. 54). This cultural relevance was successful in part because of the well-designed, highly scaffolded structure of implementation. Exhibit 3 (next page) outlines the process of scaffolding in terms of writing and digital imagery skills. Stepping the students from the bottom to the top of this pyramid over a 2-week period allowed them to become active and engaged daily writers. Another way this project was a model for culturally relevant activity is through the active involvement of family and community members as participants and audience members. Students were asked to participate alongside a very important person or people (VIPs) from their life, such as a parent, grandparent, or close member of their community. VIPs committed to several sessions where their students taught them computer skills while working on the project and presented the final versions of digital stories they had created. The presence of the VIPs and the opportunity for real conversations between VIPs and students raised the stakes for students by invoking community as an authentic audience. This combination of cultural relevance, scaffolding, and authentic audience led to improvement in students' writing skills, motivation, and interest.

With the rise of the networked world, neither culture nor community needs to be local anymore. Students can and often do identify with a number of cultures both on- and offline. Each of these subcultures has digital and/or face-to-face audiences that can be mobilized as students prepare to share their developing expertise. For example, imagine a student that creates a Minecraft how-to video, posts this on YouTube, and links to it within a Minecraft community forum post. This student is

EXHIBIT 3. THE MODEL OF DIGITAL STORYTELLING



Source: © 2005, Candice Figg (as cited in Figg & McCartney, 2010).

invoking a form of cultural identity and honing her skills by putting her emerging expertise on display to be evaluated by an authentic audience. These are the types of interest-driven activities that connected youth regularly engage in today. As such, relevant cultures and communities, rooted in either the digital world or local context, can have powerful transformative potential when integrated within learning activities. These types of authentic activities could be leveraged in formal learning environments more frequently as a way to increase engagement and support learning by underserved students.

Underserved students benefit from learning activities that provide them with opportunities to drive their own learning. These include learning opportunities that allow students to become content creators. This type of student agency was featured in three different studies and manifested in a variety of ways. It included the use of technology to provide students with a choice of instructional materials, and allow them to become active agents in their learning (e.g., making decisions about how a task was done) (Watson & Watson, 2011). Similarly, technology was used to allow students the freedom to determine the structure and framework of learning tasks when engaged in multimodal content creation (Hall & Damico, 2007). Finally, technology was used to promote agency in the context of choices about whether or not to use the technology at all (Edmonds & Li, 2005).

In a study by Hall & Damico (2007), African American high school students attended a pre-college summer course focused on digital media construction. The course was aligned to standards put forth by the International Society for Technology in Education and was focused on meaningful creation of digital texts by students. In this case, students were able to drive their own learning on multiple levels. First, students, working in groups of four or five, "were encouraged to explore a social justice problem related to their respective communities" (p. 82). Thus, they were given the choice to engage in a topic that was both relevant to their community and interesting to them. The student teams next exercised agency in the project by choosing to make either a website or an iMovie. The course provided the students with the skills and resources necessary to complete these learning activities and offered a choice as to which path they pursued. Finally, students were given complete authority over their plans for completing the project. This included the way the work was divided among the team, their design choices, and the order in which various parts of the project were completed. By the end of the summer program, instructors were facilitating student-driven learning, rather than directing it.

Activities like this one that involve students as content producers show promise in terms of student engagement, self-efficacy, and attitude towards school and learning. In a number of studies, students engaged in content creation projects demonstrated improved engagement, self-efficacy, attitude toward school, and skill development (Bottge et al., 2006; DeGenarro, 2008; Elam et al., 2012; Figg & McCartney, 2010; Hall & Damico, 2007; Lang, Waterman, & Baker, 2009). Content production can take a number of forms. For instance, students might engage in multimedia content creation that communicates their ideas and thoughts about culturally relevant themes and events (Figg & McCartney, 2010; Hall & Damico, 2007; Watson & Watson, 2011). This may be accomplished through video production (Cohen, Kahne, Bowyer, Middaugh, & Rogowski, 2012; Harness & Drossman, 2011), digital storytelling (DeGennaro, 2008; Figg & McCartney, 2010), or in other forms.

In one of the many studies illustrating the effective use of technology as an interactive tool for both practicing skills and creating new content, Maninger (2006) studied several ninth grade English classrooms with large numbers of at-risk students—including many who had previously failed English and were predicted to fail the state ninth grade reading test—ultimately outperformed other higher-tracked classes in their school on the state tests. These other classes included both on-level and Advanced Placement sections who studied the same material without technology supports. In the technology-rich classroom that was developed for the classes of at-risk students, the teacher used one-to-one computers with wireless connections to the Internet to engage students in:

> word processing, spreadsheet, database, web page production and presentation software in a variety of contexts. This flexibility provided an environment that was fun and exciting for the students. Students produced researchbased websites in place of research papers, and they discussed points of literature in BLOGS, instead of traditional handwritten journals. All of this closely resembled the world of today's teenagers that includes instant messaging, email and web-based gaming.
>
> The teacher used the laptops often and planned a special unit of concentrated use at least once each six-week grading period. For example, prior to a unit of study she would ask the students to use the laptops for discovery exercises such as web quests or museum tours. She also required the students to use advanced organizer software on the laptops to map out a paper before they began to write…An assignment concerning the Holocaust exemplifies the kind of research-based websites produced by the students. The teacher introduced the unit of study with discussion and lecture. The topics covered historical aspects and relevant current issues that tie to examples of genocide in the world today. Next, the teacher provided the students with pertinent information on citation style and writing tips. The classes then spent several days in the library accessing the Internet and books that they could use as a foundation for their research. The teacher then asked the school's instructional technology specialist to visit the classroom and establish web space and folders for the students on the school's server. The teacher spent the next few days teaching the students how

> to use webpage construction software and troubleshooting their efforts. The students were required to have a home page, three sub-pages and a reference page; each of these pages was required to be linked to each other. They were required to have at least two pictures and no more than four per page. Each student was required to plan their website in a storyboard format, and the project was graded using a predetermined rubric. (Maninger, 2006, p. 40-41)

The students, who had previously demonstrated behavioral problems and high rates of failure on the state test, were highly motivated. The researcher and the teacher attributed this to the use of technology to engage students in projects in which they would have high levels of agency and give them opportunities to practice materials that they would later encounter on the state test. When asked what it was about the use of technology that improved the students' achievement, the teacher responded:

> It gives them an atmosphere of active learning. They are involved in their learning at all times, they make their own learning decisions, and they buy into [the classroom]....With the assistance of technology, I am able to differentiate my instruction to meet the needs of individual students; they know that and want to be a part of that kind of atmosphere. (Maninger, 2006, p. 43)

One key to content creation projects is the use of scaffolding: guiding the students through a series of increasingly more complex activities that build on one another. Scaffolds may include "visuals, such as storyboards or graphic images" that stimulate prior knowledge, increase recall of key insights, and encourage imagination (Figg & McCartney, 2010, p. 54). Motivation and self-esteem are further enhanced when content creation tasks are culturally relevant and accessible, and take into account students' interests (Figg & McCartney, 2010; Hall & Damico, 2007).

The cases detailed above are clear illustrations of the way content creation might look as a single ongoing project. An alternative example comes from Lang et al. (2009), who worked with 55 Latino adolescents on a number of shorter content creation projects. In this study, students attended 16 2-hour sessions that met weekly. Within these sessions, each student had a computer and engaged in original content creation projects, such as the production of posters using Broderbund The Print Shop software that advertised positive traits about a student's ethnic group. In another lesson, students were asked to create materials for a business they envisioned themselves starting. They used software such as Microsoft Excel to track expenses, The Print Shop to advertise to potential employees, and Microsoft FrontPage to mock up a website for their business. Although this instantiation of content creation differs in terms of scope, it shares common characteristics with the earlier illustrations, including cultural relevance, interest-driven activities, structured choices, and student agency within the learning activity. Historically, these types of activities are associated with yearbooks, school newspapers, and slides for oral presentations, but the underlying characteristics could be designed into much smaller content creation projects such as blog posts, comments on articles, article annotations, social shares, tweets, or even emails. For content creation to support learning outcomes, the scope, task, and digital tool must be well aligned to the other elements of the Digital Learning Ecosystem. When these elements are well coordinated and scaffolded, underserved students often benefit from the opportunity to drive their own learning, create original digital content, engage meaningfully with content knowledge, or hone their digital literacy skills.

Conclusion

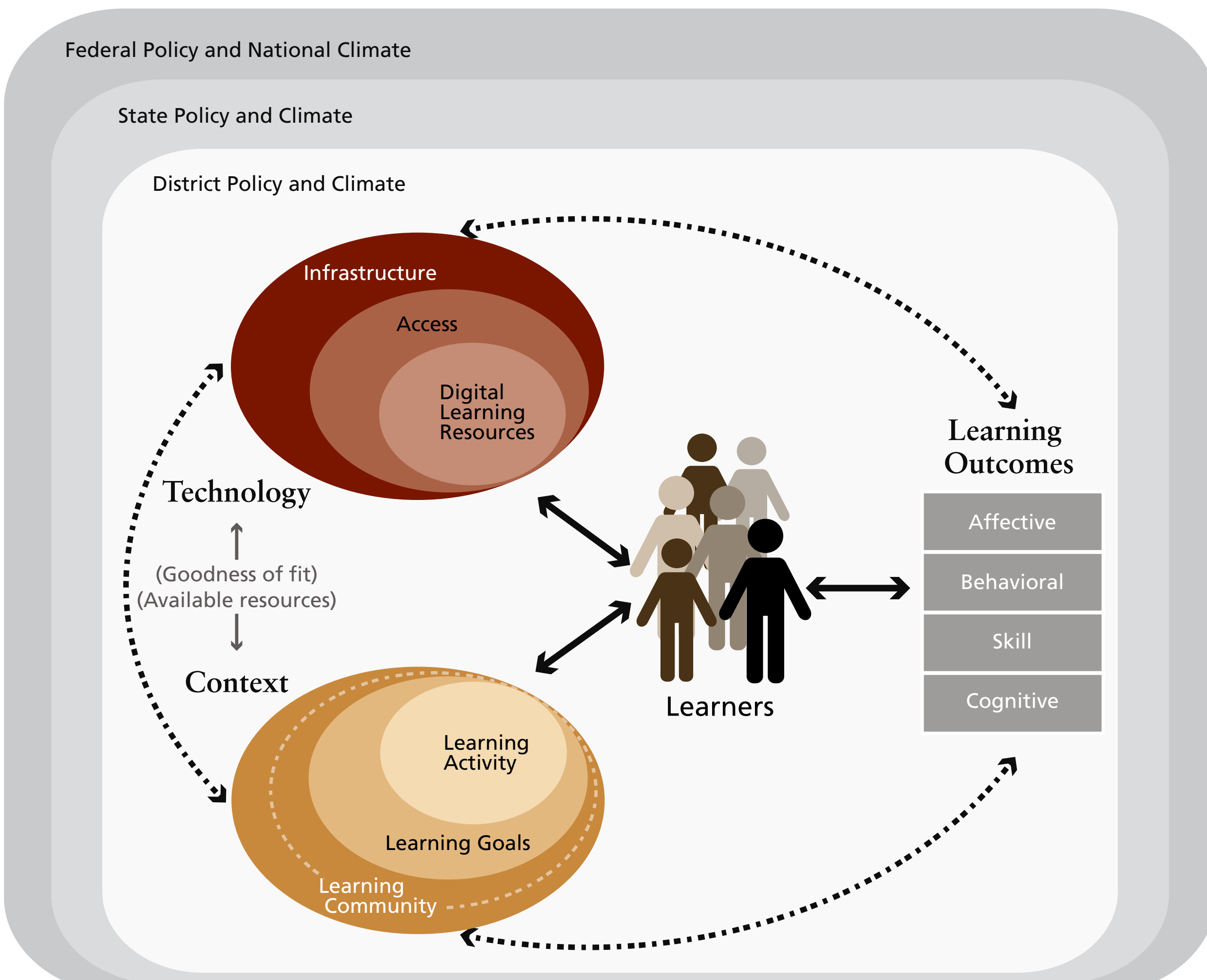
School technology access has become an issue of national priority. With increased access to technology on the horizon, educators stand at a crossroads. Do they continue with the status quo or attempt to use the rising technology levels to support those students who need it the most? Research on technology for learning by underserved students has revealed that patterns of technology use and access vary along socioeconomic and demographic lines. Underserved students use technology to practice basic skills far more frequently than others, and these types of drill and practice activities contribute little to actual learning. Additionally, evidence indicates that these students experience stronger learning benefits from tasks that promote higher order thinking skills. These are not, however, the types of opportunities that underserved youth commonly experience (Warschauer & Matuchniak, 2010). These findings indicate that educators who continue with the status quo are likely to reinforce patterns of inequity, not solely in terms of access to technology but also in terms of how the technology is used. Although issues of equitable access are far from resolved, the rising tide of technology access necessitates a new wave of dialogue dedicated to identifying and disseminating promising practices for technology use that support learning by underserved students.

We hope to contribute to this dialogue in two ways. First, we introduce the Digital Learning Ecosystem as an empirically grounded framework that provides a holistic perspective of the mutually interdependent variables shaping a technology-enabled learning environment. The application of this framework has both benefits and limitations. A major benefit of the Digital Learning Ecosystem is that it provides a detailed picture of the variables that are present when students are learning with technology. In this framework, we begin to see how these interconnected elements collectively mediate student outcomes. As such, the framework can be applied in either research or practice. As a research tool, the Digital Learning Ecosystem can be used to frame inquiry and situate findings. In practice, it can be used to support strategic planning, preparation, or evaluation. As districts, schools, and teachers prepare to use new digital tools or transform their existing digital practices, they can use the Digital Learning Ecosystem to identify elements within their systems that are strongly aligned and those that need additional support. We recommend that schools and districts use this tool to take inventory of where they currently stand in terms of digital learning, map their short- and long-term digital learning goals, and determine the supports and scaffolds that will be put in place to drive the school community from point A to point B.

The limitation of this framework is that it fails to take into account variables that were not highlighted by the researchers and educators within the studies reviewed. Examples of missing variables include peer interactions as well as district, state, and national policies. Each of these variables influences the learning environment, which in turn impacts the outcomes for learners. Exhibit 4 depicts the Digital Learning Ecosystem version 2.0, which has been lightly revised to depict peer interactions as an additional variable that influences digital learning. This limitation can be mitigated if we consider the Digital Learning Ecosystem to be an evolving artifact that must be updated and revised based on the shifts in the larger educational landscape. Future waves of scholarship, widespread changes in educational practice, the evolution of new technologies, and the way these technologies are adopted in schools will all shape future iterations of this framework.

In addition to proposing the Digital Learning Ecosystem, in this review we have begun the process of identifying and sharing promising research-based past practices that are empirically linked to improved learning outcomes by underserved students.

EXHIBIT 4. THE DIGITAL LEARNING ECOSYSTEM 2.0



Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education

Our review of the literature indicates that within the technology sphere best practices for supporting underserved youth include one-to-one access to devices and high-speed Internet connectivity. Additionally, technology tools that promote student engagement with data and provide a variety of interactions with complex content in multiple forms were identified as features of digital learning resources that support underserved students. These resources best support learning when they promote high levels of interactivity and allow students to discover insights about complex concepts (rather then receiving direct instruction on the concepts). These recommendations for infrastructure, access, and digital learning resources were evident in literature published between 2003 and 2013. Given the rapid technology evolution cycles and the shift in national adoption patterns, this list of promising practices in the technology sphere should not be considered comprehensive. In fact, by the time this article reaches publication, it will already be time for a new review of recent literature and evaluation of emerging practices.

Our recommendations related to context have slightly more staying power because the rate of change for formal learning environments is far slower than technology evolution cycles. In the literature related to the learning context, we found positive outcomes for students when digital learning activities were used to support the development of higher order thinking skills, when learning activities drew on relevant culture and community, and when students were drivers of their own learning, developing expertise and creating original content. These contextual features broadly frame the types of learning activities and learning objectives that guide all aspects of instruction, not just the moments that integrate technology. Successful long-term adoption of these kinds of objectives and activities is partially dependent on their alignment with other elements of the learning context, including but not limited to the curricular ideology and values of the school community, teachers' beliefs and experiences related to technology, classroom culture, and the time available for the activity.

From this review, we have arrived at the recommendations described above, and we consider these to be our second potential contribution to the growing dialogue about technology for learning by underserved students. We expect that this list will be revised and built upon as technology and context in U.S. schooling each continue to evolve.

Finally, our conclusions have arisen through the analysis of studies of specific students at a particular place, in a particular time, using a particular technology. Each study accounted for some, but certainly not all, of the factors that enabled or limited success for underserved students, and no single study provides detailed information about all of the variables in the Digital Learning Ecosystem. So, for those who seek to apply these recommendations, remember they are not an instructional manual for digital learning. Instead, they are merely guidelines intended to stimulate thinking and mobilize change. As we endeavor to use technology to support learning by our nation's underserved students, we must remember that the most immediately relevant beacons always come from within. Data about what is working and what is not working in your classroom, school, or district are more relevant and up-to-date than any academic article or national report. Interpreting these data within the Digital Learning Ecosystem can shed light on the multiple factors enabling or limiting student success as digital tools are utilized in new ways. There is utility in knowing what are widely considered to be promising practices, but these are only the starting point. The end point is when you find what works for your students in your school(s) with your technology today—especially if what is working today is preparing your students for the world they will encounter tomorrow and the day after, let alone the world they will inherit in the years to come.

Endnotes

1. The initial 23 reports and reviews synthesized literature on digitally mediated learning for students in grades 6–12 but was not limited to literature specifically reporting outcomes for minority, low-SES, and underprepared students. This collection was used specifically to develop the Digital Learning Ecosystem as a frame for analyzing factors that influence learning with technology. Later, the literature search for empirical works specifically reporting outcomes for minority, low-SES, or underprepared students in grades 6–12 yielded 34 studies. These articles were coded and analyzed. Results of this analysis are presented in the findings section. See Appendix A for a detailed account of the literature search and analysis processes.

2. Watson and Watson (2011) also found real-time digital feedback essential for successful digital learning experiences; they elaborate on the benefits of feedback, including helping students feel successful.

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Appendix A: Methods

Understanding the problem space: In phase 1 of the project, a prelimary search was conducted to inform our understanding of the problem space. Guided by the question, "what is already known about technology and learning in K–12?", this initial search yielded 18 relevant research reviews and reports. Five more sources were added to this set over the duration of the project. Collectively the initial works synthesized the results of over 2,000 empirial studies, preseting findings on learning outcomes associated with technology use for both general and specific learner populations.

Developing an analytic framework: After a close read and annotated outline of the reviews and reports collected at the start of phase 1, all findings were indentified, individually excerpted, and categorized according to emergent themes. This organization and classification of the evidence based findings on technology and learning provided a skeleton for the first version of the Digital Learning Ecosystem and iterations were made as necessary to reflect the findings from the 5 sources added to the phase 1 collection. The Digital Learning Ecosystem was developed as an analytic tool to be used for the systematic review of the literature conducted in the next phase of the project.

Scoping the systematic review: The formal literature review conducted in phase 2 of the project focused on research in education from journal articles, white papers, and reports published from 2003 to 2013. The selection of 2003 as the cutoff date was determined because it was the year of the last review of literature about technology for learning by underseved students. To the best of our knowledge, the most recent literature review on this subject was published in 2002 and presented a synthesis of relevant research that occurred from 1986 to 2002 (Barley et al., 2002). By restricting our search from 2003 to 2013, we seek to pick up where this left off, reassessing what is known and capturing new trends that have arisen in the last decade. Information retrieval took place in multiple stages as described below.

Building the search term: Keywords and concepts from the research questions were identified. These were searched in the Educational Resources Information Center (ERIC) thesaurus and a robust list of relevant keywords was generated using the results. Keywords included terms such as technology, technology integration, technology uses in education, secondary school, high school, under-credited, and underprivileged youth.

Collecting sources: ERIC, PsychINFO, the Australian Education Index, the British Education Index, and Education Full Text were searched for combinations of keywords appearing anywhere in research documents. The search was conducted using a complex Boolean search term constructed using the keywords above in an organization designed to optimize the relevance of results. The time range for all searches was set to 2003–2013; the source types were limited to scholarly journals and reports. All search results were pulled into a reference collection and duplicates were removed.

Enriching the collection: The text and bibliographies of each article were searched to generate a list of potentially relevant articles for the pool of studies. Field experts were asked to review citation lists and their suggestions were submitted to the collection for review in the subsequent phases. Search engines (e.g., Google and Google Scholar), education related non-profit organizations (e.g., SRI and the Joan Ganz Cooney Center at Sesame Workshop), educational technology publishers, and trade websites (e.g., *Education Week* and *THE Journal*) were searched using a combined subset of keywords. The total number of potential studies after enriching the collection was 359.

Preliminary reviews: For each of the 359 potential studies, abstracts were read (full texts were consulted as needed) and determined to be potentially relevant or not relevant. Those deemed not relevant were removed from the collection. Articles were eliminated if any one of the key constructs was not present (e.g., no technology was used and the population did not include students). This resulted in the elimination of 128 articles and reports, leaving 231 for further consideration. This process was repeated two additional times and consideration was given to the criteria for inclusion (below) and the methodological rigor. This resulted in the exclusion of another 197 studies. The remaining 34 highly relevant studies were analyzed in-depth using the Digital Learning Ecosystem (see Exhibits 1 and 4).

Setting the criteria for inclusion: Exhibit 5 illustrates the criteria for inclusion, which included the student populations of interest, the focus of technology for learning and instruction, the setting (in or out of school), and an evaluation of technology use.

EXHIBIT 5. CRITERIA FOR INCLUSION IN COMPREHENSIVE REVIEW

Population
Students in grades 6–12 Some or all students in the study were characterized as one or more of the following: • Low-SES • Racial or ethnic minority • Low achieving/not meeting academic standards/below grade level • Low parent education level • Under-credited/not on track to graduate • Underserved population
Focus
Students use technology for learning or other instructional purposes.
Setting
Study takes place in or out of school
Outcomes
The impact on the students of using the technology was evaluated qualitatively or quantitatively

Note: Including additional vetting for sufficient methodological detail and rigor, and publication after 2002.
Source: © 2015, Molly B. Zielezinski, Stanford University Graduate School of Education

Coding selected articles: After several close reads, findings from the 34 empirical studies meeting the criteria for inclusion were identified, excerpted, and organized in terms of the Digital Learning Ecosystem. The categories in this analytic framework were then revised and refined based on the fit of these findings into the existing landscape. Very few modifications were necessary to achieve alignment. Next, the 34 empirical studies selected for inclusion were coded to capture the characteristics of the research, the learning activity, and the technology. Within these categories, 22 dimensions were specified and a total of 95 subcodes were applied in the analysis of each empirical article. The results of the article analysis were assembled and findings were organized in a variety of ways. The promising practices presented in this report were selected based on themes that were reiterated across multiple studies. Also, practices were highlighted if popular themes from national education technology dialogue were addressed in a comprehensive manner within specific articles and reports (e.g., online learning).

Summary: Methods and sources by project phase: In phase 1, we gained insight into the learning outcomes associated with technology use in K–12 and the variables that are commonly reported to effect these outcomes (23 sources). The Digital Learning Ecosystem provides a visual and analytic representation of the information from these reports. In phase 2, we conducted a systematic review of empirical articles reporting learning outcomes associated with technology use by a specific subset of underserved students (359 sources considered, 34 sources selected for inclusion). The results of this review are presented in the Findings section. In the third and final phase of the project, we sought to situate the findings from phase 1 and phase 2 of the project within the current national context. Here we gathered sources that articulated student demographic data at the national level and information about technology access and use by elementary and secondary students in the US classrooms and at home (21 sources). A subset of the relevant national information is conveyed in the introduction to this report.

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