What PreK–12 Teachers Should Know About Educational Technology in 2023: A Research-to-Practice Anthology

Edited by
Richard E. Ferdig, Richard Hartshorne, Emily Baumgartner, Regina Kaplan–Rakowski, and Chrystalla Mouza
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Thanks to our family, friends, and colleagues who supported us, the authors who went through a fast but rigorous publication process, the reviewers who reviewed manuscripts, and all the teachers, teacher educators, teacher professional developers, administrators, and students who continue to do educational wonders.


*But test all things.*

*Hold on to what is good.*

1 Thessalonians 5:21 (CSB)
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INTRODUCTION

Research does not influence practice as much as researchers—and probably practitioners—would like. This is a continual problem for education writ large (e.g., Greenwood & Abbot, 2001; Rycroft-Smith, 2022) and for educational technology advocates more specifically (e.g., Norman, 2010; Weston & Bain, 2015). Scholars have made countless attempts to address this persistent challenge by publishing journal special issues, journals with practitioner sections, and even journals dedicated to practice. There have also been clearinghouses and other technological efforts aimed at addressing the research-practice gap (e.g., Finelli et al., 2014; McGann et al., 2020). While all these efforts and strategies are noteworthy, more work needs to be done by educational technology scholars to help practitioners translate research into learning outcomes. This need has been exacerbated following the COVID-19 pandemic, as educators continue to seek evidence-based approaches to leverage uses of technology for student learning in online, hybrid, and face-to-face contexts.

The purpose of this open access eBook was to respond to this need by publishing concise, educational technology chapters written specifically for preK–12 educators. The hope was to give researchers an opportunity to impact practice by translating their research into observable actions. Drawing off the open access, short-form, and rapid publication success of previous Association for the Advancement of Computing in Education (AACE) eBooks (e.g., Baumgartner et al., 2022; Ferdig et al., 2020), this publication was created to feature short chapters of no more than 2000 words (plus abstract, references, tables, figures, and appendices). We were particularly interested in chapters that combined faculty, preservice teachers, and/or preK–12 school faculty and administrators as authors.

Topics

There was no specific agenda for topics, outside of the general need to be about educational technology and aimed at preK–12 educators. We anticipated topics driven by emerging technologies (e.g., drones), pedagogy (e.g., accessibility and engagement in online learning), or specific content in relation to new tools (e.g., mathematics education through 360-degree video). We were particularly interested in cutting-edge topics that teachers are currently seeing and responding to including artificial intelligence (AI), machine learning, extended reality, data analytics, personalized learning and instruction, the Internet of Things, cybersecurity, gamification, biometrics, and blockchain.

Prospective authors were permitted to focus on a specific research study or a collection of studies. For instance, an author could write about a study they completed using ChatGPT with fourth grade students. However, rather than being a traditional research publication, authors were required to translate outcomes into practical findings. In this example, an author might discuss ways to safely and effectively use ChatGPT with a similar audience.

Alternatively, an author may have spent the last several years exploring empirical research on computational thinking. In this case, they would not necessarily report on a specific study, but rather would broadly discuss overall findings from their collection of studies. They would then use their corpus of research to create an observable list of practical implications for changing practice as it relates to computational thinking.

Further, topics did not have to be related to one sole study or a corpus of work from a single researcher. An author may have been interested in middle school math tools and could have completed a literature review and then translated that to broad research findings and resulting practical implications. The author, in this case, may have been drawing on their own research, the research of others, or a combination of both.

The General Outline of Chapters

We have found that giving authors outlines for their chapters, while understanding the potential creativity limitations, accomplishes several important things. First, providing outlines supports readability. preK–12 educators do not always spend time with academic research, and we did not want potential authors to stick to traditional journal publish-
The second positive outcome was limiting the amount of traditional research presented. This was important as many authors initially submitted chapters that were focused mostly on empirical research and not the translation to practice. We wanted authors to base their recommendations and practical implications on research, while not making this a research report.

Last, an outline and a small word limit (~2000 words) helped promote rapid review and publication. It also simultaneously maximized the appeal of the volume for practitioners who do not always have time to read lengthy manuscripts published in traditional academic outlets. The chapters underwent a remarkably rapid publication process, with the book being published only a few months after submissions. Authors were asked to adhere to the following overarching section headers, although some authors chose to add subheadings:

- **Abstract** (150–250 words) – Authors were requested to provide a concise overview of the chapter in practitioner language, stating its main purpose. This included a brief overview of the topic along with practical recommendations for readers.

- **Introduction** (~250 words) – This section was reserved for describing in layperson terms, the broader context for the problem or opportunity that was being addressed. This could have included historical context for the problem or opportunity; it may also have highlighted why the technology or the research had become relevant for education.

- **Research Review** (~250 words) – This section was specifically reserved for authors to present their research to readers. The authors were asked to use layperson terminology to summarize what the research covered about a particular topic. This could have been the results of a specific study, a collection of studies, or a synthesis of an entire area of research. However, authors were reminded to write to teachers and not to write to other researchers. They were also encouraged to use reliable references to support their claims, so readers could follow up if they wanted to.

- **Implications** (~1000–1500 words) – This section was intended to be the main part of the chapter. The authors were asked to use layperson terms to describe specific, measurable, and action-based steps resulting from the research. This could have included what readers needed to know to begin (e.g., teacher-accessible literature they should read). It may also have included links to specific software or even materials the authors had created to support their efforts. Perhaps most directly, authors were asked to imagine that a preK–12 teacher had just listened to their research talk and wanted to apply what they did in the classroom. We asked authors to consider what teachers should do to apply what the researchers had learned.

- **References/Appendices** – References and appendices did not count towards the overall word count. However, we asked authors to include enough references to provide support for their statements. We did not want the overuse of references to impede readability for teachers, but we wanted to provide additional reading opportunities. Moreover, we reminded authors that the goal of the book was to make it easy for teachers to apply educational technology research to classroom instruction. As such, we encouraged them to consider the use of appendices or shared links (e.g., Google Drive) within the appendices to any materials (e.g., videos, instructions, student examples) that would more easily facilitate application of their work in practice.

**THE SECTIONS OF THE BOOK**

This book was written to support preK–12 teachers as they learned about educational technology research and then made practical changes based on what they learned. However, within that larger goal, authors wrote about several diverse and important topics. This book, therefore, was divided into six sections to help organize the content for readers. It is worth noting that a chapter might have fit into multiple sections; however, it was placed into a section that was most relevant to the presented content.
Accessibility & Inclusion

The concern about accessibility and inclusion in education is essential. With the aftermath of COVID-19 and its impact on education, this concern is increasingly evident. Therefore, providing preK–12 teachers the tools to ensure inclusive learning is necessary. The six chapters in this section examine these important topics.

Many students with disabilities rely on assistive technologies (ATs) in their educational journeys. Harkins-Brown and colleagues (2023) explore how the principles of the Universal Design for Learning (UDL) can be leveraged to help students with disabilities and provide low-cost solutions to educators. The authors provide examples of practical applications and technological solutions to provide multiple means of action and expression, as well as multiple means of representation. UDL principles are also explored in the second chapter, from Mahoney and Nelson (2023), who encourage the use of UDL to create student-centered learning experiences. The chapter offers advice from elementary and middle school classrooms and provides worksheets together with other ideas for creating learning plans that ensure accessible technology for students while applying UDL principles. Lohman and Taylor (2023) continue discussing the importance of accessibility and using ATs in the classroom. The authors note that many K–12 teachers are unprepared to use ATs and urge educators to pursue professional development for continuing education on ATs. The chapter also provides information on locating AT needs in students’ Individual Education Plans (IEPs).

While there is an increasing number of women in STEM, the next two chapters in this section focus on getting girls introduced to STEM at an earlier age. Morris (2023a) suggests implementing hands-on STEM activities and programs to help increase interest for girls in STEM. She provides examples and ideas for after-school programs as well as integrating STEM education into the curriculum. She also offers links to national organizations that assist in increasing STEM education opportunities for girls. Similarly, Powers and colleagues (2023) use examples from a STEM program for middle school girls during the school day to encourage other educators to implement a similar approach. The recommendation is to encourage active learning, peer teaching, a supportive community, and mentoring to assist girls in STEM program.

Immigrants are projected to be one-third of the children in the United States by the year 2050 (Lander, 2018). The final chapter in this section from Paganelli and coauthors (2023) focuses on educating children on how to support immigrants and refugees as they transition into K–12 classrooms using digital escape room games. The authors argue for the need for both students and educators to be prepared for a multicultural classroom and provide ideas of how to implement similar games in the classroom.

Artificial Intelligence

The general and educational use of artificial intelligence (AI) has risen exponentially since the release of ChatGPT in November 2022 (Lampropoulos et al., 2023). It is therefore no surprise that a large number of chapters were submitted on the topic of AI, and seven were accepted. These chapters provide valuable guidelines for how to use AI in educational settings, offering insights into potential benefits and challenges of AI. Within the first chapter, Ling and colleagues (2023) discuss pros and cons of using AI tools for instructional purposes and offer examples of how teachers may use AI to facilitate their work, including generating prompts that help with the development of lessons plans, presentation slides, and feedback on students’ work. While the chapter by Ling et al. mostly overviews textual AI tools (e.g., ChatGPT, Bing Chat), the second chapter by Ferdig and colleagues (2023) extends the discussion to AI-based image generation and the benefits of AI for preK–12 education. Specifically, the authors provide useful strategies for effective prompt development and strategies for working with images, such as using caution for inappropriate content. The authors also provide examples of AI use in educational contexts. While the first two chapters overview existing AI tools, Cheng (2023) explains how to develop a self-made AI-based chatbot using the natural language processing platform Dialogflow. Cheng’s step-by-step instructions are accompanied by screenshots, which effectively assist readers in comprehending and implementing the chatbot-making process.

Although several types of AI exist, within generative AI, text generation seems to have gained particular attention. Therefore, it is unsurprising that scholars tend to explore how AI can be used for writing, and the next three chapters in this section are dedicated to this area. First, McKnight and Hicks (2023) explain the reasons behind the use of generative AI writing tools and describe what they do and why they are important. The authors introduce the Literacy in 3D model that supports teachers’ integration of generative AI for writing. Examples of writing tasks that use AI are pro-
vided, with special attention to operational, cultural, and critical dimensions. Young and Maher (2023) also discuss the potential of generative AI for writing, however, they focus their attention on students who are struggling with writing. The authors provide examples of AI tools (e.g., Grammarly, Quillbot) and show how they can support the development of writing skills. Because one of the risks of using AI is students' possible over-reliance on AI tools, the authors address ethical concerns and outline considerations with regard to the use of AI for writing. Writing is a complex process, and for foreign language learners, it poses a particular challenge. The chapter by Özcêlik and Gündüz (2023) focuses on how generative AI in the form of ChatGPT could complement and enrich writing skills development of language learners. The authors outline some benefits of AI for writing such as providing personalized feedback, developing personalized language exercises, and preparing lesson plans.

While this section primarily covers the use of AI, the concluding chapter by Kiliçkaya and Kic-Drgas (2023) tackles important concerns regarding its misuse. The authors enlist AI-written content detectors (e.g., AIChairCheck, GPT Zero) in the writing assessment process, outlining their benefits and limitations. The authors stress that careful attention to privacy concerns is crucial, as certain AI tools may not provide a guarantee of privacy for uploaded content. Consequently, the violation of privacy issues could potentially arise.

Content Area Foci

The use of technology in content-area instruction has the potential to leverage evidence-based teaching practices to support student learning. Prior literature has identified four types of technologies with the potential to support student learning including, technologies that support collaboration, gaming, and anytime-anyplace approaches (Mouza & Lavi-gne, 2012). While much research has been conducted to date on technology-integrated teaching practices broadly, chapters in this section present specific strategies and offer implications for the use of technology in content-area instruction, particularly as it relates to mathematics and literacy.

The first chapter in this section by Hodge-Zickerman and York (2023) summarizes results from over 16 years of research examining the interplay of technology and active learning in the mathematics classroom. In this chapter, active learning is used as an umbrella term for inquiry-based instruction centered on collaboration, engagement, opportunities to examine student thought process, and equity-oriented approaches. To support these practices, the authors argue for the need to move beyond efficiency, focusing on how teachers can integrate technology for tasks that could not be accomplished without digital tools. The authors provide recommendations for collaborative (e.g., Padlet) and content-specific tools (e.g., Desmos, GeoGebra) that can support group work and active engagement with mathematics content. Specific resources for teachers are also shared. The second chapter, by Kurz and colleagues (2023), describes a class on visual computing and its applications in mathematics and other STEM fields. Visual computing, which refers to the concept of processing and creating visual content, is closely examined with examples of how teachers can integrate it using various tools (e.g., Pixilart and Tinkercard). Continuing in the content area of mathematics, Miller and Courtney (2023) describe mathematics instruction that integrates pedagogy and content-area technological tools using Desmos and GeoGebra, as well as popular online resources, such as YouTube, Khan Academy and Edpuzzle, to optimize student learning. Similar to Hodge-Zickerman and York (2023), Miller and Courtney argue for the need to use technology in ways that transform mathematics instruction rather than substitute or augment previous non-technology enhanced activities.

While the first three chapters provide implications for technology-integrated mathematics instruction, the next four chapters focus on technology integration in literacy, including reading and writing. Vasinda and colleagues (2023) discuss the use of Readers Theatre coupled with podcasting to support reading fluency and comprehension. The authors provide specific recommendations for podcasting software, such as Audacity, Wavepad, and Spotify, and highlight the affordances of podcasting when combined with evidence-based reading strategies. In the next chapter, Baker (2023) extends a traditional understanding of digital literacy by introducing four digital literacy footholds, which are described as public, semiotic, product-oriented, and transitory. Baker (2023) ends the chapter by providing specific examples of using technology to support the public nature of digital literacies. Kelly-Howard and colleagues (2023) continue the conversation on digital literacies by focusing on digital writing tools and the way teacher educators prepare elementary teachers to integrate digital writing into literacy instruction. Drawing on their own research, the authors recommend practices for integrating digital writing into instruction including modeling digital writing tools, discussing the affordances and constraints of various digital writing tools, and providing students choice when completing digital writing tasks. The final chapter focuses on teaching of idiomatics – the scientific study of idiomatic and figurative language. The author defines
idiomatics as the “natural way of expressing oneself” (Liontas, 2023), and figurative language as the “creative use of language to suggest meaning beyond its literal interpretation” (Liontas, 2021, p. 32). The author provides specific strategies and technologies for teaching idiomatics in secondary classrooms.

In the last chapter of content-area foci, Macdonald and Crowley (2023) focus on the use of technology in visual art practice. Drawing on their own research, the authors present tangible technologies, such as clay and ceramics, and their application in middle school classrooms in the context of the Australian curriculum. The authors argue that clay and ceramics support student learning of rendering three-dimensional objects which can serve as precursors to understanding simulated three-dimensional design using computer assisted design tools. Further, the authors argue for the need to examine historical roots of emerging technologies and their connection to embodied experiences of working with tangible craft materials.

Gaming, Extended Realities, and Robotics

Thanks to technological advances, educators constantly benefit from innovative ways to engage learners. Among technologies that students often find enjoyable are digital games, extended realities such as virtual reality or augmented reality, and robots. Literature indicates that digital games have potential to engage learners and boost their academic performance. However, when digital games are overused or poorly selected, they may yield counter effective outcomes. In the opening chapter, Litster and colleagues (2023) provide strategies on how to effectively select games and how to detect features that are likely to engage rather than disengage learners. Teacher practices when implementing games within the context of mathematics education conclude the chapter.

Similarly, in the second chapter, Kutz and Meltzer (2023) explain how introductory algebra students can learn about linear functions using a motion simulator. The authors enlist specific steps of how to encourage students to interact with the simulator by testing, evaluating, adjusting, and retesting conjectures that facilitate meaningful simulation experiences. An overview of free simulators for learning algebra is provided to conclude the chapter.

In the third chapter, Morris (2023) points out that it is necessary for learners to practice 21st century skills, which consist of both hard skills (e.g., computational skills, design) and soft skills (e.g., communication, creativity). Morris (2023) elaborates on how such skills can be mastered using digital-based video games. Specific examples of how learners can exercise problem solving, creativity, and collaboration are provided alongside a list of links to relevant games. This chapter serves as a valuable foundation for the subsequent, fourth chapter by Stitzel and Morris (2023). The authors highlight the potential of a popular digital game – Minecraft Education – which provides students with engaging, creative, and fun learning experiences. Stitzel and Morris (2023) offer practical guidelines for effectively incorporating Minecraft Education into educational settings, along with real-life examples showcasing successful implementations of the game.

Shifting the focus from digital video games, the fifth chapter delves into the realm of another immersive technology: augmented reality (AR). Asim and Ellis (2023) explain how pre-service teachers used AR to teach biology and astronomy. Based on teachers’ perceptions from that experience, students have a positive reception to using tablets for AR activities, and the interactive nature of the learning content considerably enhances their engagement with the learning process.

Another immersive technology, 360-degree video, is the topic of the next chapter. Baumgartner (2023) enlists explicit steps guiding readers through the process of 360-degree video implementation, including the selection of the hardware and freely available videos. The author urges teachers to foster student engagement by encouraging them to take an active role in producing their own videos using 360-degree cameras. The chapter continues with valuable directions on facilitating the process of making 360-videos within the classroom, enabling teachers to empower students to become creators and further enhance their engagement with technology. While Baumgartner’s (2023) guidelines are applicable to students of various age groups, the final two chapters specifically target younger learners.

The chapter by Ibarra-Esquer and Flores-Rios (2023) presents a low-cost interactive tool designed as an alternative interface for computer applications. Young children showed high engagement with the tool as they experienced the autonomy of controlling a video game through hand-to-hand touch, rather than relying on traditional input devices such as keyboards, mice, or game controllers. Concurrently, older participants embraced leadership roles in the games, fostering teamwork and organization. This chapter concludes with comprehensive instructions for reproducing the tool design and crafting educational activities.

As we move toward the end of this section, Hall and Mulder (2023) describe learning experiences with button-operated robots for young children. Specifically, the authors provide guidelines ensuring proper design of the activities using
robots with consideration how such activities foster collaboration. The authors’ invaluable insights shed light on the effective integration of these activities into classroom settings, creating a harmonious learning environment that maximizes student engagement and participation.

Social Emotional Development and Interactive Learning

Supporting student social, emotional, behavioral, and mental health has been an important priority, especially as K–12 learners emerge from the COVID-19 pandemic (Williams & Drake, 2022). Although the U.S. Department of Education released resources and real-world examples aimed to support student social emotional well-being (Cardona & Neas, 2021), still little work exists on how to use technology to support students experiencing mental health challenges. The chapters in this section focus explicitly on the role of technological resources in supporting student social emotional learning and well-being at school and beyond. Further, as educators address learning gaps and disruptions created by the pandemic (Kuhfeld et al., 2022), it is important to look at the role of technology in creating interactive learning opportunities that support student motivation while helping educators keep abreast of new technologies.

In the first chapter, Campbell and Rujimora (2023) distinguish between different types of anxiety and emphasize the important role of teachers in recognizing signs of anxiety and creating an environment that is responsive to learner needs. The authors present different technology apps, online programs, and technology-driven activities that can be used to respond to learners’ anxiety, nurture teacher-to-learner relationships and improve the overall well-being of students. In the next chapter, Rujimora and Campbell (2023) focus on the role of technology in supporting the mental and academic well-being of students diagnosed with cancer. The authors demonstrate how children facing cancer and their classmates, can use various apps, robots, and other online tools to maintain a sense of normalcy and foster peer and teacher relationships. Following on the theme of social emotional learning, Zeybek (2023) presents a study with elementary school teachers focusing on their perceptions about the use of technology to support student social emotional learning and academic success. The study provides implications and practical recommendations for the use of digital tools in the teaching of social emotional learning, such as balancing digital and in-person social-emotional learning activities, drawing on age-appropriate social-emotional learning programs, addressing the unique needs of students in special education, and aligning social-emotional learning frameworks with technology standards.

The second set of chapters in this section examines teacher decision-making and professional development about technology integration, as well as interactive uses of technology for learning and assessment. Tofel-Grehl and colleagues (2023) address the cognitive load experienced by teachers, administrators, and professional development providers as they assess the suitability of specific technologies in the classroom. The authors explore the notion of technological instructional overhead (TIO), which is based on the premise that technology necessitates teachers evaluate their decisions about technology use based on the potential value of different tools in their classroom. The authors introduce the TIO Inventory which engages teachers in evaluating specific technologies based on three core areas: time to learn, time to teach, and potential benefits. Further, the authors present a series of cases to illustrate the differences in the application of the TIO Inventory across different technologies. Focusing explicitly on the role of teachers as learners of new and emerging technologies, Talbot (2023) discusses a self-directed learning process which addresses three areas: infrastructure, learning process, and community development. Talbot (2023) presents a sample self-directed plan which helps teachers drive their own learning by identifying their needs, developing goals, designing a flexible learning trajectory, evaluating their learning, and sharing their learning. The author also shares strategies for sustained learning through community building. Finally, Ting (2023) focuses on a specific approach to teacher learning, namely, teacher research. Building upon the SAMR framework (Substitution, Augmentation, Modification, and Redefinition), Ting (2023) provides an approach for engaging teachers in studying their own technology uses by identifying a piece of technology with the potential to enhance learning, critically considering how theory supports the use of the specific technology, implementing technology and collecting relevant data, and finally analyzing and reflecting on the process. An example is provided to illustrate the process for teachers.

Addressing explicitly the use of technology to support interactivity in direct instructional practices, Niessen (2023) presents a variety of tools and their role in actively engaging students in teaching, learning and assessment. The final chapter in this section by Morella and Gandolfi (2023) shifts attention to formative assessment and the ways in which it can be applied through technology. The author discusses implications exemplifying formative assessment technologies with potential to differentiate and gamify learning, with the goal to foster student motivation.
K–12 Online and Blended Learning

Online and blended learning in the preK–12 context became the forefront of educational research after COVID-19 (see Baumgartner et al., 2022; Ferdig et al., 2020). Many preK–12 teachers are still often required to have online or blended components as a part of their instruction. The first two chapters discuss activities that can support learners inside the classroom and at home. The next six chapters in this section give advice and ideas on how to efficiently implement online and blended learning.

The first chapter from Kosko and colleagues (2023) discuss using 3D printing and Cricut to create math manipulatives, which can support learners both in the classroom and at home. They further offer ideas for how to create a makerspace for manipulatives and provide links to quality 3D printers and tutorials. The second chapter by Brannon (2023) also explores makerspaces and 3D printing in the realm of design thinking and creativity. The author provides templates for lesson plans and resources for teachers as well as parents who may want to integrate something similar with their students.

Despite most education returning to in-person instruction since COVID-19, Barbour and colleagues (2023) argue that preK–12 teachers should still be prepared for online and blended instruction for the future. The authors give advice and lessons learned from online learning research and provide implications of what teachers should know. Borup and colleagues (2023) provide resources for those teachers who are looking to start (or are currently employing) blended learning. The authors introduce Blended Teacher Readiness framework and share a free book series based upon it.

While teaching sometimes is difficult to navigate, there are plenty of digital materials and marketplaces to help teachers in the classroom. However, the large number of materials may be overwhelming to some teachers. In their chapter, Arispe and Hoye (2023) explain how to access and integrate digital materials for teaching and learning. They not only assist teachers in effectively locating these resources but also offer valuable suggestions on how to align them with curriculum objectives, empowering educators to navigate this digital landscape with confidence. They include a guide, repository, and a reflection worksheet from their experiences working with teachers. Marketplaces are another area for teachers to get resources for their classrooms. Shelton and Archambault (2023) explore these opportunities and give recommendations to teachers who are considering use of marketplaces such as Teachers Pay Teachers. They also provide insights into the concerns associated with using resource marketplaces.

Gonzalez and Gonzalez (2023) continue the section on online and blended learning by studying principles from cognitive science and online learning research and offering advice on how to implement them into virtual and in-person spaces. They specifically look at the Welcoming Environment principle, the Minimized Cognitive Load principle, and the Multimodal Engagement principle. Included are resources and images to help teachers implement these principles in their own classrooms. The final chapter in this section comes from Keast and Keast (2023) in which they share key takeaways of their research regarding online tutors in elementary math and reading for grades 3–5. The authors’ recommendation that tutoring sessions are scheduled during the school day and teachers remain involved with the tutoring process.

CONCLUSION

Innovative researchers and educators have published chapters in this book that include important and practical implications drawn from empirical research. We hope, and believe, that these findings and recommendations will positively impact preK–12 education for years to come. If our beliefs are correct, and such work continues to impact schools and educators (particularly in this open access format), we will strive to continue this title in subsequent years.

The publication processes (i.e., soliciting and reviewing chapters) have highlighted several of the challenges that exist in the divide between researchers and practitioners. Although the volume includes 45 high quality chapters with wide applications for teacher practice, a large number of chapter proposals were not accepted. Those chapters that were accepted often went through several revisions. This process illustrated the challenges of translating research into implications for practice. It became clear that researchers are not used to writing for practitioners, while practitioners’ views of what counts as research (and where they find such research) do not always align with researchers’ perspectives.

The eBook publication process highlighted what others already knew—namely, we need more professional development for both educators and researchers. Such an outcome is crucial for staying abreast of the latest and continually emerging pedagogical strategies, research findings, and technological advancements in teaching and learning to meet the continually evolving needs of students. Notwithstanding this finding, the editors are pleased to share this eBook with you.
as an effort to bridge the gap between research and practice, making relevant scholarly knowledge more accessible and applicable to everyday classroom contexts.

Respectfully,

Richard E. Ferdig, *Summit Professor of Learning Technologies, Research Center for Educational Technology, Kent State University*

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**REFERENCES**


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We would also like to thank Gary Marks, Chris Marks, Kathryn Mosby, and Sarah Benson at AACE. They took a chance on our original eBook on teaching, technology, and teacher education during the COVID-19 pandemic and a subsequent Retrospective on the same topic. We are also grateful for allowing us to continue with this research-to-practice anthology and share the work as open access to reach a wider audience of scholars and practitioners around the world.

Finally, we would like to thank our families for their support and allowing us to give up personal time during the summer to work on this book. We would not be where we are without your love and support.
ACCESSIBILITY AND INCLUSION
Many students with disabilities require assistive technologies to equitably access instruction in their least restrictive environment. In recent years, the proliferation of one-to-one technology in classrooms coupled with the convergence of universal accessibility features in common computerized devices makes it possible for educators to offer forms of assistive technology to many students without the use of specialized equipment. Given the high rate of assistive technology abandonment discussed in the literature, it is critical that educators and students take full advantage of high-leverage, low cost assistive technology options that are available in common devices. This brief chapter outlines how the principles of Universal Design for Learning and common classroom technologies can be leveraged in classrooms, including the use of speech-to-text applications to provide multiple means of action and expression and the use of text-to-speech applications to provide multiple means of representation. The chapter provides practical applications of these universal technology solutions and how they can be integrated to support students with disabilities, as well as research-based resources and references to support educators.

INTRODUCTION

The Individuals with Disabilities Education Act (IDEA) requires that students with disabilities (SWDs) be educated in the general education classroom to the maximum extent possible (IDEA, 2004); thus, most school-age students with Individualized Education Programs (IEPs) in the United States spend 80% or more of their day in general education (USDE, 2022). Overall, there has been a steadily increasing trend in the number of classrooms that are considered one-to-one technology learning environments, where every student has access to their own computerized device (Gray & Lewis, 2021). This trend toward one-to-one technology has increased dramatically since the closure of schools due to COVID-19, given the need to transition to virtual instruction (CARES Act, 2021). Today, many educators enter classrooms where universal technologies are in the hands of every pupil. In this chapter, we will summarize the ways these ubiquitous technologies can be leveraged, as forms of assistive technology (AT), to support the inclusion and effective instruction of SWDs.
Instructional technologies, when integrated effectively, can be used to improve teaching and learning and to assist all students in obtaining academic skills. AT, as defined by the IDEA, is “any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of a child with a disability” (Section 602 (1) (A)). Prior to the evolution of universally embedded features of today’s commonly used devices, AT tended to require specialized equipment. While the adoption of one-to-one devices does not eliminate the need for specialized forms of AT for some SWDs, the increased prevalence of technology in classrooms now makes it possible for more educators to provide AT to SWDs using common, everyday tools (Koch, 2017; MacKeough et al., 2018; Nieves, 2021). This shift toward the use of mainstream technology to support the needs of SWDs is a critical milestone in inclusive education, as it promotes accessibility and greater independence for many SWDs (Boser et al., 2014).

RESEARCH REVIEW

Universal Design for Learning

Universal Design for Learning (UDL) is an instructional framework that emphasizes minimizing barriers and maximizing accessibility for all learners (Center for Applied Special Technology [CAST], 2018). UDL addresses learner variability in classrooms while ensuring high expectations and is rooted in research from education, educational psychology, cognitive science, and neuropsychology (Meyer et al., 2014). The framework identifies three neural networks for learning: the affective network (the “why” of learning), the recognition network (the “what” of learning), and the strategic network (the “how” of learning) (Rose & Meyer, 2002). UDL integrates the science of learning into the classroom through three principles: multiple means of engagement; multiple means of representation; and multiple means of action and expression. Each principle is broken into three guidelines to offer additional specificity. The guidelines include checkpoints to provide examples and demonstrate links to empirical research. Additional research evidence to support each UDL principle can be found at https://udlguidelines.cast.org/more/research-evidence#checkpoints.

While the integration of UDL can be achieved without the use of technology, the UDL checkpoints emphasize how technologies support the framework, such as optimizing access through the use of technology tools like AT and the use of modern, flexible, and accessible media (CAST, 2018). The use of one-to-one devices is beneficial for SWDs, because it may help students to feel more included among their peers, increase their confidence, and reduce the stigma associated with specialized equipment (Nieves, 2021). Additionally, the use of universal devices in the classroom addresses the barriers commonly identified in the research on AT adoption, including issues related to teacher training, funding, and availability (Bouck, Flanagan, et al., 2012; Bouck, Shurr, et al., 2012; Koch, 2017). These barriers have been shown to lead to high levels of AT abandonment (MacKeogh et al., 2018). Given that universal features are increasingly available in common devices, it is imperative that educators are knowledgeable about universal usability features to mitigate these barriers.

IMPLICATIONS

High-Leverage, Low Cost Solutions

The proliferation of one-to-one devices within classrooms means the high cost associated with high-tech assistive technologies has already been invested. It is critical that school districts fully leverage technology purchases by investing time into learning about built-in accessibility features available within the most common instructional technology devices. For example, students using Chromebooks, iPads, and laptops equipped with Microsoft Office all have access to accessibility features that allow these devices to function as AT for SWDs.

That said, learners may not be familiar with technology resources or have the associated skills or practice in using them. Considering the UDL practice of coaching learners toward autonomy and expertise, in figure 1, we suggest below two key examples of high-leverage, low cost solutions that can be accessed from mobile devices in the classroom: Text-to-Speech (TTS) and Speech-to-Text (STT).


**Figure 1**

Assistive technologies to address UDL principles

<table>
<thead>
<tr>
<th>UDL Principle</th>
<th>Examples of Learner Variability Addressed</th>
<th>Assistive Technology Tool Available on Common Digital Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide Multiple Means of Action &amp; Expression</td>
<td>● Fine motor weakness&lt;br&gt;● Temporarily injured hand(s)&lt;br&gt;● Reading disability&lt;br&gt;● Dysgraphia</td>
<td>Speech-to-Text</td>
</tr>
<tr>
<td>Provide Multiple Means of Representation</td>
<td>● Low vision&lt;br&gt;● Missing glasses&lt;br&gt;● Temporarily disrupted vision (i.e., migraine, epilepsy, concussion etc.)&lt;br&gt;● Reading disability&lt;br&gt;● Attention support needs</td>
<td>Text-to-Speech</td>
</tr>
</tbody>
</table>

These foundational resources can be used in conjunction with many more advanced AT tools and reach a wide range of learner variabilities. For example, students using Chromebooks, iPads, and laptops equipped with Microsoft Office have access to accessibility features that allow these devices to function as AT for SWDs. See Appendix A for a list of accessibility guides that can be used to navigate features in common classroom devices.

**Providing Multiple Means of Action and Expression: Speech-to-Text Applications**

The UDL principle, “provide multiple means of action and expression” includes the following guidelines: *provide options for physical action* and *provide options for expression and communication* (CAST, 2018). These guidelines emphasize variability among learners’ ability to produce written work. For example, a student may struggle to write a paragraph due to difficulties with fine motor strength or coordination necessary to hold a pencil or type on a keyboard. Another student may struggle to spell words due to a reading disability. UDL emphasizes that variability among learners’ strengths and skills is expected and should be planned for proactively within the inclusive classroom. Therefore, becoming familiar and confident with the STT software on classroom devices can support a wide range of students with writing tasks.

STT software broke through to popular consciousness in the 1990s with the advent of *Dragon Naturally Speaking*. In its early days, the technology was complex, difficult and time consuming to train on, and prohibitively expensive for many learners. Today’s STT are not burdened by such barriers. Major platforms with embedded STT including Google Suite, Microsoft Office, and Apple’s iWork suite have advanced, including easy to use STT tools that are built into these platforms. These contemporary tools require no training, are generally highly accurate, and are free to use with their corresponding platforms.

In addition to documented positive implications for supporting students with learning disabilities and language learners, STT has been shown to have broad positive utility including for use by those learning new writing strategies, as a resource to guide self-directed language learning, improved writing quality and reduced writing effort in elementary students-and may increase learners’ “abilities to produce texts with fewer errors, provide help with spelling and improve reading comprehension and word recognition” (Matre & Cameron, 2022, p. 1). Many of these gains are believed to be
achieved through the way that STT enables greater fluency of expression during the writing process, scaffolds auxiliary skills such as spelling, and reduces frustration and effort during the writing process.

As with any skill or technology, the use of STT applications need to be taught to learners and teachers who need to understand it as a process rather than a one-and-done method. This method generally looks like:

1. **Prepare**: Brainstorm, outline, or otherwise pre-write ideas that will appear in writing.
2. **Speak**: Use STT to express ideas, outlining “chunks” of information onto the page (paragraphs or more).
3. **Revise**: Correct errors, add clarity, and/or improve formality or flow after using STT or using STT to make further edits.
4. **Review**: Where possible, include peer review or use text-to-speech software to have the work read back to the author. This helps correct any final changes related to tone and clarity.

Given the ubiquity of STT tools in existing high-use platforms (e.g., Google Suite and Microsoft Office) and the demonstrated benefits that STT may have for many learners, this is a prime example of an AT Tool that can be taught and provided as an ongoing option for learners at all levels.

**Providing Multiple Means of Representation: Text-to-Speech Applications**

The UDL principle, “provide multiple means of representation,” highlights the need for different pathways for learners to consume information. This principle includes the guideline to *provide options for perception*, which emphasizes the need to provide alternatives for visual information, such as printed text. UDL reminds educators that visual perception as well as comprehension of visually presented information are variable among learners. A student may have difficulty reading printed text due to low vision or a reading disability and neurodiverse students may struggle with printed text due to variability in their attentional control.

Another built-in accessibility support that can be used as AT and/or inclusive technology in the learning environment is TTS or read-aloud technology. TTS software enables the device to read selected text aloud to the user. Options to have words highlighted as the text is read, alternate voices, and speaking rate adjustments are common features. This is different from using basic read-aloud technology such as Voice Over, which is primarily used for learners who are blind or visually impaired to access their devices. In this context, we are referring to TTS software where learners can customize their reading experience by adjusting the speaking rate, voice, and word highlighting functions.

There have been huge advances in TTS technology over the past decade. Not long ago, TTS software was often a standalone installation, requiring an extraneous purchase, monitoring of licenses, extensive training, and support. However, in today’s inclusive technology ecosystem, devices from iPads, iPhones, to computers all come pre-packaged with TTS software. Apple (iOS, OSX) has a feature called “speak selection”, Google has a feature called “select to speak,” and Microsoft has a feature called “Immersive Reader.” All of these are free to users and can be turned on with a few simple adjustments to the device.

In addition to having documented benefits in reading comprehension and reduction of mind wandering for learners with dyslexia and learning disabilities (Bonifacci et al., 2021; Wood et al., 2018), there are other benefits of using TTS software with learners. These benefits include support for decoding, reading comprehension, and increases in vocabulary development.

Furthermore, providing TTS as a tool for writing as part of the editing process can help learners more accurately identify errors. The combination of visual and auditory cueing can help learners understand errors and improve their comprehension of what is written (Keelor et al., 2020). This also helps learners to be more resourceful and knowledgeable as part of the UDL framework where they can match the appropriate tool to the task at hand without permission from the teacher. Many SWDs require AT to access the general education curriculum and to be successful in their least restrictive environment; see Appendix B for a list of resources that are designed to assist educators in identifying specialized forms of AT and ensuring digital accessibility to SWDs.

Many SWDs require AT to access the general education curriculum and to be successful in their least restrictive environment. When leveraged appropriately, universally embedded features such as STT and TTS software that are available in today’s common device platforms make it possible for educators to integrate AT without additional training or funding and with a reduced stigma to SWDs. The strategies discussed in this chapter outline the practical benefits and
approaches to using this software with SWDs, in alignment with the UDL framework. However, it is critical that the use of AT with each student with a disability be carefully considered by the student’s IEP Team so that the form of AT selected is aligned with the student’s unique needs to ensure that the student is afforded a free appropriate public education (FAPE) in accordance with the IDEA.

REFERENCES


APPENDIX A

Accessibility Guides for Commonly Used Classroom Devices

- Get Started with Accessibility Features on the iPad:

- Making Chromebooks Accessible for People with Disabilities:
  https://www.google.com/chromebook/accessibility/

- Guide Dogs Apple Accessibility Guide:

- Discovery Windows Accessibility Features:
  https://support.microsoft.com/en-us/windows/discover-windows-accessibility-features-8b1068e6-d3b8-4ba8-b027-133dd8911df9

APPENDIX B

Digital Accessibility and Assistive Technology Resources

- National Center on Accessible Educational Materials:
  - https://aem.cast.org/get-started/resources

- National Assistive Technology Act Technical Assistance and Training (AT3) Center:
  - https://at3center.net/

- The PATINS Project:
  - https://www.patinsproject.org/resources/aem

- mATch up Tool from Maryland Assistive Technology Connection Hub:
  - http://cte.jhu.edu/matchup/
Applying Universal Design for Learning: A Practical Approach for Planning Equitable Learning Experiences with Classroom Technology

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Designing learning experiences with technology that are student-centered, accessible, and equity-focused is an ongoing challenge facing preK–12 teachers. In this chapter, we highlight how to apply Universal Design for Learning (UDL) in creating student-centered learning experiences that are supported by technology tools and emphasize re-envisioning learning experiences to celebrate learner variability, choice, and collaboration. Using examples set in elementary and middle school classrooms, we use a variety of pedagogical choices to illustrate how UDL and technology for learning work together. We also provide teachers with a guide for creating their own classroom learning plans using a four step process including: (1) describing a learning experience with an emphasis on central concepts and skills, (2) designing strategies to break down the layers of complexity and build in opportunities for student choice, (3) systematically applying the UDL framework, and (4) identifying accessible technology tools that will allow students to fully engage in the learning experience while allowing for choice, creativity, and collaboration.

INTRODUCTION

Universal Design for Learning (UDL) is a research-based framework that focuses on helping educators to create learning experiences, materials, and spaces that are inclusive and accessible through providing multiple means of engagement, representation, and action and expression for students (CAST, 2018).

- Multiple means of engagement emphasizes the multiple ways in which students can be motivated or engaged in learning experiences, taking into account diverse culture, identities, background experiences and interests of the students.
- Multiple means of representation helps teachers to address the different ways students perceive and comprehend information by providing options and scaffolding using multimedia and multisensory meaning construction to facilitate communication.
- Multiple means of action and expression focuses on how students develop and demonstrate their learning by providing options for physical actions, expression of knowledge and skills, and increasing capacity to become independent learners with supports for executive functioning (CAST, 2018; Kieran & Anderson, 2019).

UDL is an invaluable tool for educators who are seeking to design and implement student learning experiences using technology. UDL helps educators to see that inflexible curricular materials and methods serve as barriers to diverse learners (Hitchcock et al., 2002). For educators to be successful with UDL, they need to apply it in culturally equitable and inclusive ways. The end goal is for educators to think flexibly about learner characteristics, assessment, and engagement and the barriers students may have in accessing the instruction and materials (Kieran & Anderson, 2019).
RESEARCH REVIEW

Technology can make learning accessible in ways that were impossible before; however, technology alone cannot solve educational problems. What educators do with technology is just as important as having access to it (Reich, 2019). Superficial or ineffective applications of UDL or technology can create new problems and exacerbate existing problems. A deep dive into UDL with technology in mind gives teachers the tools and strategies to meet students’ variable learning needs (Novak & Tucker, 2021).

The goal of UDL is to design for learner variability (Novak & Tucker, 2021). UDL guidelines provide a systematic method of curricular review with an end goal of accessibility and flexibility (Glass et al., 2013). In a successful UDL curriculum, teachers provide materials in a flexible format, supporting transformation between media and multiple representations of content to support all students’ learning to increase accessibility (Hitchcock et al., 2002). For example, “… while it might be agreed that students should be able to read, modern literacy requires much more than processing text. This new literacy requires deciphering information through multiple mediums such as text, video, audio, graphics, emojis, and interactive simulations” (Basham et al., 2020, p. 77).

Providing digitally rich learning opportunities is also essential to educational equity. Decades of research demonstrate that more affluent school districts have more technologies and use the technologies in student-centered and engaging ways, whereas lower income schools tend to eliminate opportunities in favor of equality rather than equity and to replicate teacher-centered approaches with technology tools (Reich, 2019; Reich & Ito, 2017). It is with this mindset that we will provide examples of how to incorporate digital tools and learning choices for all students with maximum flexibility for teachers to make use of technology tools.

IMPLICATIONS

Universal Design for Learning (UDL) has been developed as a powerful framework for learning design. We have noticed that not every preK–12 organization is aware that it exists, although it can be a very effective tool especially for schools with increasing amounts of access to technology tools. While UDL is an excellent way to incorporate technology for learning in meaningful and rich ways, it is also complicated and layered. Like anything we want to do well as educators, it takes time to try, truly understand, and apply in practice.

In this section, we give examples of classroom learning experiences that have been developed with the UDL framework in mind for teachers to reference while exploring UDL in their own classroom and provide a brief planning guide with questions meant to prompt educators to incorporate engagement, representation, and action and expression (CAST, 2018) into their learning activities. The examples illustrate how UDL can effectively work in multiple lesson structures, content areas, and grade levels. They are meant to demonstrate how teachers can think through each lesson component while centering learner variability.

The following approach has been effective in our experience, and we share it as a process for other teachers contending with the complexities of designing learning experiences with technology:

1. Describe: Start by describing a learning experience you are planning, emphasizing the central concepts, skills or big ideas you want the students to learn.
2. Design: Develop strategies to break down the layers of complexity and opportunities for choice throughout the learning experience. Keep in mind the diverse culture, identity, interests, background knowledge, and learning needs of the students in your class.
3. UDL Application: Check your design for strategic and embedded opportunities for multiple means of engagement, representation, and action and expression following the UDL Guidelines.
4. Technology: Identify the technology tools you have access to in your school district that will best support your students in fully engaging in this learning experience, including familiar and new technology tools, new ways of using them, supporting independent student use, and providing students with choices.

We offer technology suggestions last because these decisions about technology tools are driven by the combination of thinking and planning done in the other sections, the available technologies, and the specific characteristics of learners in a particular classroom. These learning experiences are designed to be accessible, equitable, and inclusive – not limited by the need for specific tools. We encourage teachers to use this strategy for thinking through the design process.
to optimize use of the technology tools they have available by focusing on student-centered applications of technology tools. Appendix A includes a reflective planning guide with questions to guide educators in each of these steps with their particular teaching context in mind.

The first example of this planning approach details a second-grade learning experience on internal and external characteristics using both literature and personal reflection as windows into understanding and appreciating others (see Example 1: Elementary: Internal and External Characteristics). We used a familiar structure for this learning experience of whole class, group practice, and independent expression but layered complexity and opportunity for choice in each of the stages. It helped us to use a familiar lesson structure as a starting point to be consistent with classroom routines for students and appropriate scaffolding, but we did not let the structure stifle possibilities for creative learning or use of technology in our planning. We incorporated visual thinking strategies into this literacy lesson to help students build transferable skills and provide options for expression of learning. During independent expression, students apply their learning of internal and external characteristics to self-portraits using a medium of choice for the students. Here we emphasize the opportunity for student choice among both digital technology options and other materials like art supplies. Embedding technology throughout the school year in a variety of academic and creative uses can build students’ interest and confidence in making independent choices for self-expression to enhance literacy learning and reflections on identity.

Example 1: Elementary: Internal and External Characteristics

<table>
<thead>
<tr>
<th>Learning Experience Description</th>
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<tbody>
<tr>
<td>Second grade reading lesson on identifying and analyzing Internal and External Characteristics. Big Idea: This lesson helps students to understand their own identity and the identities of others and to build appreciation through literature of the diverse qualities and experiences of others.</td>
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<tr>
<th>How to Layer Complexity and Opportunities for Choice</th>
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<tbody>
<tr>
<td><strong>Whole Class:</strong> Begin the experience with Visual Thinking Skills (VTS) using purposefully chosen art that represents a variety of characteristics to notice and analyze. The teacher collects adjectives as they come up, posts or writes them on the student display and discusses the definition of an adjective. An adjective wall is begun, and students add to it over time.</td>
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<tr>
<td><strong>Group Practice:</strong> Groups have several artists’ self-portraits representing multiple cultures and points of view to choose from and then practice the VTS protocol to describe artwork and characteristics.</td>
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<tr>
<td><strong>Independent Expression:</strong> Students create a self-portrait that represents their internal and external characteristics using a medium of choice. Students find peers with similar external or internal characteristics in their portraits and share their work. Students find peers who have different external or internal characteristics in their portraits and express appreciation for their differences. Self-portraits will be displayed with student permission.</td>
<td></td>
</tr>
<tr>
<td><strong>Next Steps:</strong> The next class interactive read aloud is one that highlights the main character’s external and internal characteristics and is a point of focus for callback to the students’ self-portraits and works of art.</td>
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<tr>
<th>UDL Application</th>
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<tbody>
<tr>
<td><strong>Engagement:</strong> Students will have the opportunity to help build the adjective wall, work together to describe self-portrait examples, explore and express their own identities, and learn about the identities of others.</td>
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<tr>
<td><strong>Representation:</strong> The teacher will provide examples of adjectives, create the adjective wall, and provide diverse examples of self-portraits.</td>
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<tr>
<td><strong>Action and Expression:</strong> Students who use multiple tools for construction and composition: The choice of expression in the self-portrait format gives students the agency to create with confidence.</td>
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<tr>
<th>Incorporating Technology for Learning</th>
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<tr>
<td>Shared use of technology for whole class and group activities may include classroom display to optimize viewing of artwork and creating the word wall in Google Jamboard or Seesaw. For independent expression, the teacher should provide access to any app or tool. Options can include craft paper and markers, Minecraft, Microsoft Paint, Tayasui Sketches, blocks, Seesaw, photo filter apps, clay, or craft supplies.</td>
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</tbody>
</table>
The second example offers a new take on teaching history through a biographical approach with original data collection for middle school students (see Example 2: Middle School: Modern History through Contextualized Biographical Research). In this example, we challenged ourselves to rethink the biography unit to deeply consider what we really want students to learn from reading about the lives of others, including transferable skills, knowledge, and historical understandings. Structuring this as an inquiry exploration has the potential to spark interest and motivation among students. Layering complexity and opportunity for choice to the inquiry structure starts with a student interviewing a person in their family, school, or community. Using this interview as a starting place, students will learn about the historical events that touched this person’s life and put them into a broader context of events in history, making the connection between local and global perspectives. Technology supports emphasize choice and efficiency throughout the process making audio recording and transcribing possible for middle school students, scaffolding their project management, and building an interactive product with an authentic audience in mind. We have chosen examples of possible technologies to demonstrate that well-designed learning activities can benefit from a variety of technology tools and educators can work within the resources they have to provide access and choice for students.

Example 2: Middle School: Modern History through Contextualized Biographical Research

<table>
<thead>
<tr>
<th>Learning Experience Description</th>
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<tbody>
<tr>
<td>Biography Research: Rather than the typical assignment about an accomplished person in history, middle school students are challenged to consider the context of an individual’s life and what was happening in the world around them to create a collectivist view of history.</td>
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<table>
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<tr>
<th>How to Layer Complexity and Opportunities for Choice</th>
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<tbody>
<tr>
<td>Inquiry Exploration: Students will choose a person in their family, school, or community to interview about their life with a focus on their memories of major historical events. Students have access to a timeline of major events that occurred over the last 70 years and have prepared interview questions to ask.</td>
</tr>
</tbody>
</table>

| Collect and Analyze Data: Students will review interview transcripts to analyze relevant historical events. They will choose one historical event to focus on for their own research. They will identify key words and research additional information on the topics and events addressed by their interviewee to put them in historical context. |

| Interpret and Synthesize Results: Students will determine big ideas from their data including both relevant information about the event and the related personal experiences of their interviewee. |

| Whole Class Collaboration and Sharing: The class creates an interactive timeline of the past 70 years of history addressing the events and people researched by the members of the class. Students will make connections among shared experiences, highlight different perspectives, and understand the parallel and intersecting experiences of people living at the same time. |

| Next Steps: Share with an authentic audience. Students will share the final class timeline with the interviewees and present to other school (ex., another class or grade) or community audiences (ex., local historical society) as available. |

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<th>UDL Application</th>
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<tbody>
<tr>
<td>Engagement: Students have individual choice in who they interview and what related world event they research. They build community through connecting with their interviewee and collaborating with peers in building the timeline.</td>
</tr>
</tbody>
</table>

| Representation: Students integrate background knowledge with new learning by using multiple types of information and highlighting patterns, big ideas, and relationships. |

| Action and Expression: Teacher provides supports for the students to record their data with a variety of digital or paper-based tools, for example a Canva graphic organizer, or a voice recorder app. Lesson is designed for class to be able to self-monitor and share progress in the collective timeline closing activity. |
**Incorporating Technology for Learning**

Students choose their technology for recording an interview, transcribing voice-to-text, and documenting research notes. Class uses a collaborative project management software such as Google Keep to manage workflow and monitor progress on the interactive timeline project. Students choose and use an app to create and share their interactive timeline, examples: Padlet, Pikto Chart, Visme, Canva.

In Appendix B, we provided two additional examples of using this planning approach. The first is a multi-disciplinary learning experience using a makerspace for elementary school students and the second is a foods lesson for a Family and Consumer Science class for middle school students. In these examples, we want to emphasize the potential use of this planning approach across content areas and grade levels. We have used lessons from our own experience in P-8 classrooms to demonstrate how familiar teaching content can be re-envisioned to be more accessible, equitable, and inclusive with the support of technology.

We have included the Liberatory Design for Equity Process (Anassie et al., 2021) as a learning experience structure for our Family and Consumer Science (FACS) example. The internal and external characteristics and biographical research examples use very familiar lesson structures, and we wanted to push the boundaries of how we consider our learning experiences by including design thinking. The Liberatory Design for Equity Process is a specific design-thinking framework that focuses on empathy by asking students to notice and reflect throughout their design process. This helps students to consider their own biases and perspectives, reflect on their learning, and understand the perspectives of others. We chose to apply this process to a recipe adaptation experience to help students develop agency and make food that is inclusive to a wide variety of individuals. In our planning we think through each of the phases of the Liberatory Design for Equity process, what they could look like in a middle school FACS class, and how they can be supported through technology.

In our final example of an elementary media center makerspace experience, we have taken a specialist classroom that often has limited instructional time and provided students an efficient way to make learning choices. Students have the opportunity to practice research and design-thinking skills with continuity of practice from day-to-day. The example we have used is fashion design, but it is one of many station choices available to students when they return to their media and technology learning scheduled throughout the week. Other stations might include coding, LEGO robotics, electronics, cardboard architecture, bookmaking, or stop motion video production. We have included a graphic that demonstrates what a Google Slides or PearDeck digital choice board might look like for students entering the makerspace. Each dot has a recognizable set of student initials and will be moved via touchscreen to that student’s station of choice for the day. As each student completes a project at their station, a choice of individual or group learning celebration is made, and the student will then move on to the next station of choice. The importance of a celebration cannot be emphasized enough, as we feel it demonstrates for the students, and even reminds us as teachers, that joy can be found in learning.

We hope that educators will use these examples as inspiration for approaching technology use in their classroom in ways that are student-centered, meaningful, accessible, and equitable. Technology expands what is possible in education. Using it with thoughtful intention, we can provide all our students with engaging learning opportunities. For more information and resources on UDL and how to apply it, please see Appendix C.

**REFERENCES**


## APPENDIX A

### Reflective Planning Guide for K–12 Teachers

<table>
<thead>
<tr>
<th>Original Learning Experience: Describe the lesson that you’re imagining or needs some alteration.</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What are the core concepts and skills at the heart of this lesson?</td>
</tr>
<tr>
<td>● What are the limitations, barriers, or challenges that you face teaching the lesson and that the students face in learning during this lesson?</td>
</tr>
<tr>
<td>● Why will students want to learn about the topic that is the focus of this lesson? Why will the lesson topic matter to them?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revised Learning Experience Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What will you change?</td>
</tr>
<tr>
<td>● Does the core of the lesson address diversity, equity, and inclusion?</td>
</tr>
<tr>
<td>● What perspectives are represented in this lesson? Does it address diverse cultural perspectives?</td>
</tr>
<tr>
<td>● Ultimately, how do you want your students to learn and grow by participating in this lesson?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How to Layer Complexity and Opportunities for Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What is the overarching lesson structure?</td>
</tr>
<tr>
<td>● How can you vary the lesson structure to optimize engagement and motivation through inquiry, discovery, and experience?</td>
</tr>
<tr>
<td>● What cultural and community resources can support and optimize the relevance of the lesson?</td>
</tr>
<tr>
<td>● How will the lesson support high-level thinking in culturally relevant ways?</td>
</tr>
<tr>
<td>● Using a chosen lesson structure, how can the UDL framework amplify and transform the learning experience to offer a variety of choices for the learners?</td>
</tr>
<tr>
<td>● What are the next steps for the learning experience?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UDL Application</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engagement:</strong></td>
</tr>
<tr>
<td>● What <a href="#">UDL guidelines for providing multiple means of engagement</a> are essential for this learning experience?</td>
</tr>
<tr>
<td>● How are learners engaging with materials and ideas?</td>
</tr>
<tr>
<td>● What will motivate them to learn?</td>
</tr>
<tr>
<td>● How does the lesson provide opportunity for collaboration and community?</td>
</tr>
<tr>
<td>● Does the lesson provide opportunity for meaningful choice?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Representation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What <a href="#">UDL guidelines for providing multiple means of representation</a> are essential for this learning experience?</td>
</tr>
<tr>
<td>● How will you deliver content and learning materials as the instructor?</td>
</tr>
<tr>
<td>● What formats will be most useful and engaging?</td>
</tr>
<tr>
<td>● What materials will you use to scaffold understanding?</td>
</tr>
<tr>
<td>● How will students be supported in constructing meaning and generating new understandings?</td>
</tr>
<tr>
<td>● Does the learning experience center and celebrate diverse perspectives and experiences?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action and Expression:</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What <a href="#">UDL guidelines for providing multiple means of action and expression</a> are essential for this learning experience?</td>
</tr>
<tr>
<td>● Are students able to choose technology tools to best develop and experience their own learning?</td>
</tr>
<tr>
<td>● Do students have the opportunity to use technology tools to collaborate and communicate?</td>
</tr>
<tr>
<td>● Do students have support for executive functions throughout the learning experience?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Incorporating Technology for Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>● What elements of this lesson can be transformed for the better by using technology?</td>
</tr>
<tr>
<td>● Which tools will you use for each step?</td>
</tr>
<tr>
<td>● Are there any technology tools that you can repurpose for this learning experience?</td>
</tr>
<tr>
<td>● What technology tools can help you to provide choices for students?</td>
</tr>
<tr>
<td>● Do the technology tools have accessibility and privacy features?</td>
</tr>
</tbody>
</table>

[Link to blank, printable version of the reflective planning guide](#)
### Learning Experience Description

**Middle School Family and Consumer Science-Recipe Adaptation:** Students will find and adapt an existing recipe by changing ingredients to fit a specific diet. The diet options might include Gluten-Free, Dairy-Free, Vegetarian, Vegan, Renal-Friendly, Sugar-Free or Low Sodium/Heart Healthy. This lesson helps students develop agency in making food that is inclusive of the needs of a wide variety of individuals.

### How to Layer Complexity and Opportunities for Choice

Using the [Liberatory Design for Equity Process](https://example.com) (2021), students will experience each of the design stages with opportunities to notice and reflect throughout the process.

#### Empathize and Define

Students will begin by researching and choosing their recipes. They will be given an EdPuzzle playlist to work through, with the purpose of understanding each specific diet’s needs. They will then research ingredient substitutions and direction edits needed to meet the challenge of adapting their chosen recipe to fit a specified diet.

#### Inquire and Imagine

As a class, develop questions and criteria for a successful recipe, i.e., what will they be looking for, tasting for while testing the results. Students have option to sketch out or create photo collage of visual goal for final product.

#### Prototype

Students will draft their recipe adaptation and create a shopping list by sourcing ingredients from grocery store website, using assigned budget amount as guideline for spending. They can then conduct initial and repeated testing of the recipe.

#### Try

One option is for groups to first trade recipes with other groups or students to have them follow the directions they’ve given. When the project is completed, groups can present food with brief reflection on learning about the process of adapting recipes followed by a class taste test.

#### Next Steps

Students will compile and design a digital cookbook of all the recipes complete with photos of actual products, share with community members, and invite feedback from members of these dietary communities.

---

(Anassie et al., 2021)
UDL Application

**Engagement:** Students will develop self-assessment and reflection skills. This includes monitoring feedback, responding, and adjusting their work.

**Representation:** Students will work through the correct vocabulary and symbols used in a recipe to aid the understanding of menu options with regard to specific diet needs. The teacher can scaffold support by providing information to students on conversion and substitution to give them basic applied understanding of food science.

**Action and Expression:** Students are challenged to examine their own biases and preferences and how they might affect our food choices to better understand those of others.

### Incorporating Technology for Learning

Students will have the option to research recipes online. The playlist of information on a variety of diet options and needs will be delivered with EdPuzzle in quiz format. Recipe will be annotated with the Kami app to keep track of notes and comments from group. Budget and shopping list will be a collaborative spreadsheet sourced from a grocery store website for teacher’s shopping trip. An online AI tool could be used as scaffolding for finding dietary substitutions in recipes.

### Learning Experience Description

**Grades 3-5 Makerspace Station-Fashion Design:** A series of makerspace stations will focus on understanding qualities of functional and accessible design and how design is an expression of identity and culture.

#### How to Layer Complexity and Opportunities for Choice

**Whole Class Overview:** The media classroom is set up with makerspace stations that are complete with supplies and task-specific challenge cards directing students to choose and explore text options (print and/or digital) that describe diverse fashion artists and fashion expressions.

**Stations:** Students set goals for their day, using ideas they see or imagine to sketch out their ideas and create using materials at the station or even brought from home. Students research, process, engage with materials, take a 2D design and make it 3D, and incorporate elements they learned about from representative texts or playlist included at station.

**Organization and Flow:** Use a digital attendance board where students indicate their station choice for the day and update their status. An exit ticket with a brief plan for the next time at the end of each lesson will help students to monitor their own progress and set goals.

**Share:** Our regular makerspace practice is to celebrate a completed project. Students can choose their audience from whole group, small group, or teacher-only to present their learning, followed by a question-and-answer opportunity with teacher and/or peers.

**Next Steps:** Student is able to choose a new makerspace station from the options provided when class resumes to begin a new project.

### UDL Application

**Engagement:** Makerspace setting optimizes students’ level of individual challenge due to high levels of interest, resilience, and problem solving. At this particular station, students choose to learn about fashion or designers of interest so that they can incorporate inspiration into their own work using the creative supplies provided to create model designs in 2D or 3D.

**Representation:** Multimedia examples include a variety of creators in the field of fashion and textiles.

**Action and Expression:** Students choose how their learning is incorporated into their design, they choose how to present (to their table, teacher, or whole class), materials they use.
Incorporating Technology for Learning

Students choose their learning experience every day using a Pear Deck slide show (link to Google Slides example) on a digital touch screen. Each station has an iPad for reading directions, playing instructional videos, or conducting research as needed.

APPENDIX C

UDL Suggested Readings and Materials

Websites
- CAST is the nonprofit education research and development organization that created the Universal Design for Learning framework and UDL Guidelines https://www.cast.org/
- The UDL Guidelines https://udlguidelines.cast.org/
- The Universal Design for Learning Implementation and Research Network https://udl-irn.org/
- Universal Design for Learning: Inclusive Classrooms from Reading Rockets, a national multimedia project focused on supporting educators and parents helping young children to read https://www.readingrockets.org/article/universal-design-learning

Books

Articles
Podcasts
- Episode: If Equity is a Priority, UDL is a Must [https://www.cultofpedagogy.com/udl-equity/](https://www.cultofpedagogy.com/udl-equity/)
- Show: Think UDL [https://thinkudl.org/](https://thinkudl.org/)

Videos
- UDL at a Glance from CAST: [https://youtu.be/bDvKnY0g6e4](https://youtu.be/bDvKnY0g6e4)
- Small Open Online Course Video Series from ISTE: Universal Design for Learning and Apps
  - Universal Design for Learning Overview: [https://youtu.be/500dhPNZfHg](https://youtu.be/500dhPNZfHg)
  - Multiple Means of Engagement: [https://youtu.be/nTwhcroMAaU](https://youtu.be/nTwhcroMAaU)
Assistive Technology in the Classroom: Tips for Inclusive Classroom Teachers

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Assistive technology (AT) devices and supports are tools that support the success of children with disabilities in the public school classroom. Despite the fact that the use of AT is considered a best practice and is legally mandated under the Individuals with Disabilities Education Act (IDEA), general and special education teachers report feeling unprepared for using AT in their classrooms. This chapter offers K–12 classroom teachers with basic information about assistive technology and its use in their own classrooms. Specifically, information is provided about (a) locating AT needs in students’ IEPs, (b) using AT in the general education classroom, and (c) personal professional development to continue learning about AT.

INTRODUCTION/CONTEXT

Public school classrooms include children with a variety of learning needs. The National Center for Education Statistics (2022) reports that 15% of all children in the public school classroom have a disability that qualifies them to receive special education services. For these students, their learning may be supported through technology tools, including assistive technology (AT). Assistive technologies are devices and services that assist people with disabilities in accessing the general education curriculum, as well as other aspects of daily living. The Individuals with Disabilities Education Act (IDEA, 2004) identifies two types of assistive technology that must be considered when developing an Individualized Education Program (IEP): devices and services. The definitions for each of these can be found in Appendix A. This chapter will provide teachers in general education K–12 classrooms with a brief overview of assistive technology, as well as what they should know in order to support students in their classrooms who require AT in order to access the curriculum.

RESEARCH REVIEW

Assistive technology is mentioned throughout many of the laws and acts defining special education (e.g., Americans with Disabilities Act, 1990; IDEA, 2004; Section 504 of the Rehabilitation Act, 1973) and was independently recognized with the Technology-Related Assistance for Individuals with Disabilities Act (Tech Act, 1988). The Tech Act was reauthorized as the Improving Access to Assistive Technology for Individuals with Disabilities Act (Assistive Technology Act) in 2004. The reauthorization ensured funds were available for school systems to access resources related to AT.

In addition to being mandated under IDEA, the use of assistive technology is considered a best practice in special education and its use aligns with the High Leverage Practices (HLPs) as outlined by the Council for Exceptional Children and the CEEDAR Center (McLeskey et al., 2017). The HLPs are the evidence-based instructional practices that support the learning and development of students receiving special education services (McLeskey et al., 2017). Appendix B identifies the specific HLPs related to AT.

Many teachers may not comprehensively understand what constitutes AT, the special education laws supporting/defining it, and how it can be applied in the school systems (Bouck, 2016; Thomas et al., 2019). Previous research indicates that general education teachers are unprepared for supporting the needs of children with disabilities, including their
assistive technology needs (DeSimone & Parmar, 2006) and may feel uncertain or nervous about their ability to support students using AT devices (Leatherman & Wegner, 2022). As vital members of the IEP team, general education teachers must understand the components of the IEP and how to identify supports, such as assistive technologies, that a student may need in order to access the curriculum.

**IMPLICATIONS**

It is clear that the use of AT is of the utmost importance in the public school classroom and all teachers must be prepared to support students in accessing and using AT on a daily basis. With this in mind, we advocate that specific and ongoing teacher training on the use of AT is critical for the success of all learners in the general education classroom. Specifically, we have identified three training recommendations, as well as specific tools that can be used in each of these areas to enhance teachers’ understanding of AT.

**Implication 1: Teachers need to know how to identify AT in students’ IEPs**

There is a legal requirement under the Individuals with Disabilities Education Act (IDEA) that the IEP team must meet at least once per year and consider an individual students’ annual goals and the supports they will need to meet those goals. One type of support that must be considered is AT. In some states and school districts, the IEP form includes a specific place to document AT needs. If there is not a place for AT in the document, devices can be written into the Accommodations and Modifications section, while services may be considered part of the Special Education Services section.

Assistive technology is divided into three basic categories: low, mid, and high tech. Low tech devices do not require a power source and are easily accessible and simple to use (e.g., pencil grips, slant boards, counters, visual aids). Mid tech devices usually require a power source, like batteries or outlet, and can be learned/taught relatively fast (e.g., audio-books, calculators). High tech devices typically have programmable parts, require a power source, and often take time to learn and then implement (e.g., speech to text, augmentative and alternative communication [AAC] software).

Taylor et al. (2020) offer a six-step framework for AT use in the general education classroom; the first step is identifying the AT that students need to be successful. A student’s IEP may include one or more AT devices, which may be required at certain times of the school day or throughout the entire school day. Appendix C offers an example of how AT may be written into an IEP, but keep in mind that each school district has a slightly different format for IEP writing. After locating a student’s required AT as listed in the IEP, teachers should learn when and how that AT will be used in their own classrooms. This may be outlined in the IEP itself, but if not, we advise asking the special education teacher or case manager for guidance.

**Implication 2: Teachers must support students in using the AT in the classroom**

Once teachers have identified the AT that students will be using, they need to prepare to use that AT in their classroom. The second step in the Taylor et al. (2020) framework for AT use is to evaluate the students’ AT use in the classroom to identify the extent to which they are using the AT, as well as when and how it is being used. Teachers should also consider if the student can, or should, use the AT to a greater extent.

Next, teachers must consider upcoming classroom learning objectives and plan for how the AT will be incorporated into the lesson. This planning may involve support from the special education teacher, other education professionals, and possibly the student. After careful planning, the teacher should teach the lesson and then reflect on how the AT supported (or did not support) student learning. With this information in mind, they should plan for AT use in future classroom instruction.
Implication 3: Teachers must actively engage in professional learning on the topic of AT

While most classroom teachers will receive some training on special education, including AT, during their teacher preparation program, they must continue learning. In order to ensure that professional development related to AT meets their individual needs and the needs of the students they teach, teachers need to identify the specific AT devices that are being used in their classrooms or that might support their students. Using this information, they should seek out both formal and informal learning about AT in general, as well as about specific AT devices. These trainings might be in the form of conferences or webinars. Alternatively, teachers may design their own professional learning through reading books and research articles about AT or completing learning modules on the topic. Appendix D offers recommendations for materials that can be used by teacher preparation programs, schools and districts, and individual teachers to support initial and ongoing learning about AT.

The public school classroom includes children with a variety of learning needs. In order to ensure that the needs of children are addressed, technology supports should be utilized. For children with disabilities receiving special education services, assistive technology (AT) may be vital for meeting their learning needs. As outlined in this chapter, best practices in using assistive technology require that general and special education teachers receive initial and ongoing training on the use of, and legal requirements for, assistive technology.

REFERENCES

APPENDIX A

IDEA Definitions for Assistive Technology

Part B, Subpart A, 300.5 Assistive technology device.
Assistive technology device means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of a child with a disability. The term does not include a medical device that is surgically implanted, or the replacement of such device.

Part B, Subpart A, 300.6 Assistive technology service.
Assistive technology service means any service that directly assists a child with a disability in the selection, acquisition, or use of an assistive technology device. The term includes—
(a) The evaluation of the needs of a child with a disability, including a functional evaluation of the child in the child’s customary environment;
(b) Purchasing, leasing, or otherwise providing for the acquisition of assistive technology devices by children with disabilities;
(c) Selecting, designing, fitting, customizing, adapting, applying, maintaining, repairing, or replacing assistive technology devices;
(d) Coordinating and using other therapies, interventions, or services with assistive technology devices, such as those associated with existing education and rehabilitation plans and programs;
(e) Training or technical assistance for a child with a disability or, if appropriate, that child’s family; and
(f) Training or technical assistance for professionals (including individuals providing education or rehabilitation services), employers, or other individuals who provide services to, employ, or are otherwise substantially involved in the major life functions of that child.

APPENDIX B

High Leverage Practices & Assistive Technology

| HLP 1: Collaborate with professionals to increase student success. |
| HLP 4: Use multiple sources of information to develop a comprehensive understanding of a student’s strengths and needs. |
| HLP 5: Interpret and communicate assessment information with stakeholders to collaboratively design and implement educational programs. |
| HLP 13: Adapt curriculum tasks and materials for specific learning goals. |
| HLP 19: Use assistive and instructional technologies. |
APPENDIX C

Assistive Technology in a Mock IEP

Does the student require assistive technology devices or services?

Yes [X]  No

If yes, please indicate the AT required

Text-to-speech for written assignments
Option to use computer or tablet for written work
Audiobooks paired with written text for reading assignments
Pencil grip for written work

APPENDIX D

Websites & Online Learning Modules for Learning about AT

<table>
<thead>
<tr>
<th>Resource Title</th>
<th>Weblink or Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRIS Center Module</td>
<td><a href="https://iris.peabody.vanderbilt.edu/module/at/#content">https://iris.peabody.vanderbilt.edu/module/at/#content</a></td>
</tr>
<tr>
<td>Assistive Technology: An Overview</td>
<td></td>
</tr>
<tr>
<td>Assistive Technology Internet Modules</td>
<td><a href="https://atinternetmodules.org/">https://atinternetmodules.org/</a></td>
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<td>Connect Module</td>
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<tr>
<td>Assistive Technology</td>
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<tr>
<td>Assistive Technology</td>
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<tr>
<td>Understood.org</td>
<td><a href="https://www.understood.org/en/articles/assistive-technology-what-it-is-and-how-it-works">https://www.understood.org/en/articles/assistive-technology-what-it-is-and-how-it-works</a></td>
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<tr>
<td>What is Assistive Technology?</td>
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<td>PBS Learning</td>
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<td>Move to Include</td>
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<td>Early Childhood Technical Assistance Center</td>
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<td>Assistive Technology</td>
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<tr>
<td>Global Report on Assistive Technology</td>
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<tr>
<td>Assistive Technology Devices</td>
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</table>
There is still a need to increase the interest of girls in STEM and technology contexts. One way to do this is through the implementation of preK–12 programs and curricula aimed at increasing interest in STEM by emphasizing hands on experiences, connecting girls with role models, and building intrinsic motivation for continuing studies in STEM or technology. Implementing such programs can also help change thinking about women’s place in STEM and technology careers. In this chapter, examples of programs that focus on girls in technology will be provided and discussed. Additionally, step-by-step instructions and examples of how to incorporate these types of programs into preK–12 classrooms through curricular choices will be presented.

**Keywords:** girls in STEM; girls in tech; preK–12 education; educational programs; extracurricular activities

**INTRODUCTION**

There is still a strong need to focus on girls in STEM and technology for several reasons. For example, women in STEM and technology careers are greatly underrepresented. Moreover, educators have a responsibility to build a community where girls know they are acknowledged, needed, and have the resources necessary to succeed (González-Pérez et al., 2020). PreK–12 educators should aim to advertise and implement tech programs that help lessen the gender gap. When girls engage in technology programs or technology curriculum that focus on them, it helps increase self-efficacy and motivation (Yucel et al., 2006). It can also help build interest in applying to colleges that emphasize STEM majors (Demetry & Sontgerath, 2017). There are many different educational programs and curricula that focus on girls and coding, girls and gaming, girls and engineering, and girls and technology such as Girls Who Code and Girls Who Game. The development of programs like these can occur as extracurricular activities; they can also be integrated into the existing school day. Regardless of when it happens, such programs can encourage and build on students’ interests.

**RESEARCH REVIEW**

Research indicates that extracurricular programs that focus on girls have provided many benefits to the participants (Stewart et al., 2020; Walan, 2021; Yucel et al., 2006). For instance, Stewart et al. (2020) explained that the DesignHER code camp (which was created to intrigue middle school aged girls with technology focused careers) helped provide fun developmental learning experiences for middle school girls. DesignHER code camp had an emphasis on fashion and retail (Stewart et al., 2020); students engaged in hands-on coding experiences and were able to see the behind-the-scenes of retail (Stewart et al., 2020). The benefits for girls in this program included gaining a larger view of STEM careers (Stewart et al., 2020). Similarly, Walan (2021) determined in their study, which assessed the outcomes of a makerspace program focusing on girls and drama activities, that many of the girls in the study gained an interest in STEM when participating in the makerspace program. Furthermore, participation in the community helped develop 21st century skills for these participants (Walan, 2021). Findings from this study suggested that it may be necessary to develop a program that combines other areas (e.g., fashion) with STEM interests when thinking about the engagement of participants (Walan, 2021).

It is also important to recognize that role models in these programs play an important role in developing girls’ attitudes towards STEM (González-Pérez et al., 2020). For example, González-Pérez et al. (2020) determined that exposure to professional and personal experiences of female role models helps build interest in STEM fields. Packard & Nguyen (2003) also recommended that students take a more active role in their mentorship by seeking out their own role models.
This helped demonstrate that seeking mentorship is not a weakness (Packard & Nguyen, 2003). It is also important to acknowledge that girls can create role models in themselves through programs and curricula that emphasize their own design and work. Spieler et al. (2019) found that design activities which focus on girls help emphasize girls’ intrinsic motivation. This suggests that girls can find motivation in oneself when they are supported in their creations and designs through programs and curricula that focus on them.

**IMPLICATIONS**

Before deciding to include a program or curriculum that focuses on girls in tech or STEM in a school and following the step-by-step instructions provided, teachers first need to decide the type of program or curriculum they would like to implement. There are many different types of extracurricular programs and clubs funded by national and local institutes including programs that focus on girls in coding, girls and gaming, and girls in STEM. Some programs will require funding, others are free (see the Appendix for some suggestions of different types of programs). There may also be ways in which curricula in the classroom can emphasize girls’ experiences in technology, STEM, game design, etc. Teachers should talk to colleagues, parents, administrators, and tech specialists for suggestions about implementing an extracurricular program or in-class curriculum. Teachers should also consider reaching out to local institutes, districts, colleges, and universities to see if there are any opportunities to enroll their students in their programs.

Second, teachers should observe their students’ interests. There may be an area in which their students are lacking that could be the focus of a program, after school club, or curriculum choice teachers hope to implement. Teachers should also talk to their students to discover their interests. This will help teachers determine if a focus of a program is needed.

**After-school tech or STEM programs focusing on girls**

If teachers would like to begin an after-school program or club emphasizing girls in technology or STEM, they will need to complete at least seven steps.

1. Identify participants for these programs.
2. Decide the ages of the participants in the after-school club or program. It is important to acknowledge that there may be contexts in which older students may be more appropriate. For instance, an after-school club or program that focuses on coding or computational thinking may be more appropriate for students in grades three or higher.
3. Determine what type of technological tools are needed for the after-school club or program. For example, teachers will need to determine if they need high speed internet, Chromebooks or other devices that access the internet, hand-operated input devices like a mouse with a scrolling component, or other technological tools.
4. Determine where the after-school club or program will meet. If the school is not available, the after-school club or program may need to meet at another location.
5. Designate a facilitator or leader of the after-school club or program. If teachers are the facilitator of the after-school club or program, they will need to organize time outside of class to plan activities and receive necessary training to implement the activities. If teachers designate someone else to be a facilitator for the after-school club or program, they need to make certain that the facilitator plans activities and receives necessary training.
6. Determine the cost of the after-school club or program, which may involve organizing fundraisers.
7. Determine when the after-school club or program will take place and how long it will last.

Once completing each of these steps, the after-school club or program will be able to begin. Teachers should be flexible and expect change throughout the implementation process, as activities and participants’ interests may shift throughout the process.

One example of a national extracurricular program that emphasizes girls in technology and STEM through coding is Girls Who Code. Girls Who Code’s main initiative is to close the gender gap of entry-level tech jobs in coding (Girls
Who Code, n.d.-a). The program involves an after-school club for girls in grades three through twelve and a summer program for high school students (Girls Who Code, n.d.-b). The organization provides resources that help support the club which include tech spotlights, self-guided tutorials, interactive activities, mentors, etc. (Girls Who Code, n.d.-b). Similar coding programs like Girls Who Code have found that coding programs help increase interest in coding as well as confidence for students who identify as women (Wang et al., 2019). Teachers interested in implementing this specific program should reach out directly to the Girls Who Code organization. This is just one example of a national organization emphasizing girls and coding, however there are many similar programs available.

Another example of a national extracurricular program that focuses on girls in technology and STEM is Girls Who Game. Girls Who Game gives opportunities for girls to experience video gaming, to learn about STEM, and to engage in the development of computational thinking and problem solving (Dell Inc., 2023). The program itself offers communities in which coaches, mentors, and role models work directly with students (Minecraft Education, 2021). Initially, students in this program engaged directly with Minecraft Education which is an educational digital-based video game in which players can create block designs in the game with an educational focus (Minecraft Education, 2023). However, in 2019 the program evolved into leadership opportunities with Esports challenges, or competitive professional gaming competitions in which players compete in gaming against one another (Minecraft Education, 2021; Willings, 2021). Girls Who Game stresses the importance of girls developing leadership roles. Teachers wishing to implement the organization, Girls Who Game, should contact Dell Inc.

Teachers can also create their own after school club or program that focuses on girls in technology and STEM. For example, there are many technological tools and platforms available that can help teachers emphasize STEM and girls’ experiences at a low cost or no cost (see the Appendix for some suggestions of additional technological tools teachers can implement in their own club or program). It is important to acknowledge that more planning may be required to efficiently execute an after-school club or program without support from a national or local organization. Adopting a flexible attitude will be necessary to find success in implementation.

**Tech and STEM curriculum focusing on girls**

Teachers should also consider implementing curricular choices in the school day with a focus on girls in STEM and technology. There are several steps teachers can follow for success.

1. Determine the type of curriculum to implement that can nurture their students’ interests in technology or STEM contexts. For example, some students may be interested in mathematics, design, storytelling, drama, science, fashion accessories, makeup creation, sports, etc. Therefore, teachers should incorporate these interests in specific lesson plans that meet necessary learning outcomes.

2. Determine if technological tools are needed to successfully meet the needs of the lesson. For instance, a teacher may be able to address learning outcomes in a geometry lesson while focusing on girls’ interests by using a specific gaming platform or project tools. Whatever teachers decide to implement, they will need to learn how to use the tool, how implementation may function in their classroom, how students will use the tool in a lesson, what pedagogical strategies may be nurtured, etc.

3. Stress the importance of girls having a place in STEM, as this can help change their students’ thinking (Fisher et al., 2015). This can occur through class discussion in lessons.

4. Consider offering opportunities for same-sex group engagement. Same-sex group engagement will help build their students’ interests, creativity, and group work as it will aid in developing girls’ confidence (Fisher et al., 2015). If same-sex group engagement is not possible, teachers should consider designating leadership opportunities with a focus on girls as leaders.

*Minecraft Education* is an example of a technological tool that can be implemented in a STEM lesson plan and focuses on girls in technology and STEM. *Minecraft Education* provides educational lesson plans in many curricular subjects with a focus on girls’ interests. For example, Uberoi (2017) explained that their *patterns and motifs* lesson on *Minecraft Education* emphasizes art and geometry. In the patterns and motifs lesson, students will be able to connect patterns with art and geometry as well as discover stories in the patterns (Uberoi, 2017). The overall focus of the lesson is on art, design, and geometry (Uberoi, 2017). Uberoi (2017) claims that this lesson can be engaging for girls especially if
girls love creating patterns and engaging in motifs. It is recommended that teachers use their students’ interests to inspire their choice of lesson on Minecraft Education.

Another example of a technological tool and program that can help emphasize girls in technology and STEM is Scratch. Scratch is a free coding program where students can learn the basics of computational thinking and coding skills through block-based coding (Scratch Foundation, 2022). Through Scratch, students can create digital stories, games, and animations (Scratch Foundation, 2022). Scratch offers many tutorials on its platform. Additionally, there are other Scratch lesson plans that emphasize girls experiences which are available through Google Education’s CS First Curriculum and Girls Who Code. For example, Girls Who Code offers a free lesson plan in digital storytelling animation which emphasizes a woman in tech spotlight and offers students the opportunity to build a story project. Within this lesson, students can draft their own story, build that story in Scratch, take their story to the next level, and share it with their peers. This lesson is especially useful for girls who may have an interest in storytelling and creativity. Again, teachers should use their students’ interests as inspiration for lesson plan implementation when incorporating a focus on girls in technology and STEM with Scratch. Implementing a focus on girls in curricula in this way will help teachers motivate their students and will ultimately help their students acknowledge that there is a place for girls in STEM and technology.

REFERENCES


Wang, S., Andrei, S., Urbina, O., & Sisk, D. A. (2019, October). A coding/programming academy for 6th-grade females to increase knowledge and interest in computer science. In 2019 IEEE Frontiers in Education Conference (FIE) (pp. 1–8). IEEE.


APPENDIX

After-school tech and STEM clubs/programs focusing on girls (*=discussed in implications)

- Black Girls Code: https://wearebgc.org/events/
- Chick Tech: https://chicktech.org/about/
- Girl Coders: https://girlcoders.net/patches/scratch/
- Girls Engineering Change: https://www.girlsengineeringchange.org/get-involved
- Girls Make Games: https://www.girlsmakegames.com/
- Girl Start: https://girlstart.org/
- Ignite Worldwide: https://www.igniteworldwide.org/about/
- Techbridge Girls: https://www.techbridgegirls.org/what-we-do/ - programs

Technological tools used in curriculum focusing on girls (*=discussed in implications)

- Glitch: https://glitch.com/
- Kaggle Kick Starter Data: https://www.kaggle.com/datasets/kemical/kickstarter-projects
- Minecraft Education*: https://education.minecraft.net/en-us
- Scratch (FREE)*: https://scratch.mit.edu/
  - Tutorials*: https://scratch.mit.edu/ideas?ref=create-learn.us
- Trinket: https://trinket.io/
INTRODUCTION

Inequity for females in STEM (science, technology, engineering, and mathematics) is a well-documented and long-standing issue. Despite efforts to increase gender diversity and promote equal opportunity, women remain underrepresented in STEM careers. According to a National Science Foundation report, women represent only 28% of workers in science and engineering occupations in the United States, and this underrepresentation is even more pronounced in computer science and engineering, where women make up only 25% and 15% of the workforce, respectively (NSF, 2019).

In this chapter, the authors first review literature that focuses on selected programs for teaching and mentoring girls in STEM. The benefits of such interventions, either in-school or after-school, are included in the review to support curriculum development for educators. Next, the authors describe the middle school STEM Girls class developed by educator Lisa Gustenelli at St. Vincent Ferrer Catholic School in Delray Beach, Florida, which aims to help address the problem of female underrepresentation in STEM. The elective course empowers girls in STEM by allowing them to engage in hands-on STEM projects in a learning space just for girls. In turn, they share what they have learned about STEM by teaching younger students of all genders around their school. The young girls also engage with community partners through a collaboration with an elementary school serving rural and migrant children in Indiantown, Florida, and a local university. Research-based recommendations for educators seeking to implement a STEM program for middle school girls in their schools are provided. The ways the program contributes to girls’ knowledge and attitudes toward STEM through active engagement, peer teaching, a supportive learning community, and activities with female STEM mentors are shared to provide a model for other educators to consider.
RESEARCH REVIEW

Facilitating STEM education early, especially for young girls, supports the goal of building solid foundations for STEM literacy, according to the Committee on STEM Education of the National Science and Technology Council (2018). Franz-Odendaal and Marchand (2022) described a STEM summer camp at a Canadian University for 12–16-year-old girls. The program consisted of hands-on activities that science professionals and graduate students created. The program also employed a small group mentoring model that incorporated discussions with female STEM mentors to share career pathways, a typical day at work, and any setbacks they had along their professional path. Although the program was successful, at the end of the 10-year period, they did not observe that the local K–12 curriculum had incorporated STEM. The authors suggested an ambassador’s program where students could share their experiences with peers through social media and video to encourage ongoing participation in STEM activities. Another idea was to incorporate a girls’ leadership training program for students from past programs who could guide girls in future endeavors.

The importance of mentoring is supported in the literature through a variety of STEM programs for young girls. For example, Crowder and Whittle (2022), two female engineers-turned-educators, designed a free four-day STEM camp for middle school girls where the community has one of the lowest household incomes in the state. By involving the community, local businesses, parents, and volunteers, the implementation costs were kept low. The camp was designed using Bandura’s (1977) self-efficacy framework and playful learning pedagogy to build positive STEM attitudes and confidence for pursuing STEM careers. An all-female volunteer team engaged younger participants to enhance a sense of belonging. Activities included: using a forensic chemistry kit to type synthetic blood, making bouncy balls using chemical reactions by safely combining common household materials, building remote-controlled robots, and solving mathematical logic problems. The participants returned to serve as volunteers who mentored younger girls at future STEM camps while enrolled in higher-level STEM coursework. The study results suggest that such camps can improve STEM attitudes and self-efficacy of girls from underserved communities. Another positive outcome was that many teen volunteers continued college STEM studies to obtain degrees in various STEM fields (Crower & Whittle, 2022).

Mentoring is important for young girls exploring STEM in their studies and as future careers. The importance of female role models in promoting women’s interest and participation in STEM fields is emphasized by inspiring mathematics enjoyment, expectations of success in STEM topics, and young girls’ aspirations for future STEM study and careers. When girls are motivated through engaging in STEM activities under the mentorship of female STEM role models whether in-person or through computer-based interfaces, their expectations of success are higher with enhanced self-efficacy, self-concept, and commitment to STEM (González-Pérez et al., 2022). Another program for middle school girls partnered in small groups once a week in an after-school program with female university students in STEM degree programs for two academic semesters. The mentors developed a program for middle school girls that included lectures, hands-on activities, videos, and guest speakers on topics focused on engineering, basic science, and mathematics skills. Each topic spanned two weeks and included lectures, videos, and hands-on activities (Holmes et al., 2012). Although there are a variety of forms of girl STEM programs found in the literature, one common thread of successful programs is the importance of mentoring.

IMPLICATIONS

The STEM Girls class at St. Vincent Ferrer is a current example of an initiative to promote young females in STEM directly embedded in the regular school day. It was created in 2022 as an alternative to coeducational elective technology classes for sixth through eighth-grade girls. The STEM Girls class meets twice per week in a room that used to be a computer lab but was recently transformed into a makerspace. The technology-rich environment consists of an interactive whiteboard surrounded by worktables, a 3D printer station, built-in storage for STEM kits, educational robots, and virtual reality headsets. The girls bring laptops to class to use software such as Tinkercad to design 3D printing projects. Educators can utilize the subsequent recommendations to incorporate a STEM Girls course within their own school.

Recommendation 1: Foster STEM Skills Development through Active Engagement

Research suggests that active engagement through meaningful lessons provides opportunities for young students to practice skills in STEM (National Science and Technology Council, 2018). The STEM Girls learn skills like design
thinking, building and testing designs, and coding through active engagement in their classroom. Therefore, recommendation number 1 is to be sure to include plenty of activities that encourage active engagement when designing STEM programs. For example, this may involve building and testing a robot, as shown in Figure 1.

**Figure 1**

* A STEM girl testing a robot

**Recommendation 2: Incorporate Peer Teaching**

Another crucial component of the STEM Girls class is peer teaching. Research has shown that students who teach concepts to their peers demonstrate better understanding and retention of the material than those receiving traditional instruction (Schwartz & Bransford, 1998). This can involve teaching younger students within the same school or out in another school through a community partnership. Therefore, recommendation number 2 is to incorporate peer teaching into the STEM program to promote deeper learning of STEM concepts. For instance, the STEM Girls go to classrooms around their school to teach younger students lessons that infuse STEM concepts and technologies. An example of a lesson the girls have taught involves showing kindergarteners how they can use the Blockly app to make a robot move. The girls use iPads to install the apps they need to sync up with technology tools like robots. The robot can be implemented as a motivational tool in solving math problems. The girl teaching the younger children can ask them for input on how to program the robot to move to a flash card with the correct answer to a math problem on the floor. The benefits of this peer teaching approach were evident in the responses to reflection questions the STEM girls provided. One STEM Girl explained in her reflection how helping younger learners was something she liked the most about being in the class. “I really enjoy working with little kids, seeing their eyes light up in joy as they experience their line of code working or figuring out a puzzle,” she wrote.

Another way the STEM Girls serve as peer teachers are by planning and putting on science fairs for younger students. The girls were challenged with designing a Science Fair and Expo of fun, hands-on science activities that younger students could easily repeat at home. Each STEM Girl developed an activity and conducted it with classes of
younger students at their school. Examples of science experiments the girls presented are shown in Appendix A. The girls created a podcast to explain science concepts and share this electronically (https://voicethread.com/myvoice/thread/20932898/133377985/123791243). Through the partnership their teacher developed with Hope Rural School, they were also able to extend the reach of their activities to the largely migrant elementary school in Indiantown, Florida. Examples of STEM activities the girls completed with Hope Rural School are shown in Figures 2 and 3 below.

**Figure 2**

*A STEM girl teaching how to move and control a dash robot*

![STEM girl teaching dash robot](image1.png)

**Figure 3**

*A STEM girl teaching 3D printer modeling*

![STEM girl teaching 3D printing](image2.png)

**Recommendation 3: Building a Supportive STEM Community**

Implementing a Community of Practice (CoP), a group that shares a common interest in a topic and comes together to achieve shared goals collaboratively, is recommendation number 3 for building a successful STEM program for girls.
A CoP can foster relationships among members, enabling learning to occur within a culture of support, trust, and mutual understanding (Swift, 2014). Forming a CoP establishes a comfortable space for female learners to work together to formulate solutions to STEM challenges. Applying this approach, the STEM Girls class aims to inspire a sense of STEM belonging and confidence in girls. One of the STEM Girls wrote about how she liked this aspect of the class, stating, “I like how we get together in groups and talk about our passion and what we like.”

The STEM Girls could have signed up for a number of other elective courses such as music, art, or even a coeducational Artificial Intelligence course. When asked what motivated them to choose STEM Girls instead, some mentioned being a part of a group of STEM learners for girls. One girl wrote, “When I saw it on the electives list, I immediately decided to join due to my love of technology and women in STEM.” Another girl explained, “I wanted to get involved with other girls that like building or anything else in STEM.” Being a part of a female-only group was also what some of the girls said they liked most about the class. When asked, “What do you like most about being a STEM Girl?” one girl wrote, “It’s only for girls and it’s really fun.” Another girl wrote she most liked “Having a judge free environment, and space to let your mind wander, to make ideas and fun ways to learn” is what she likes the most.

**Recommendation 4: Empower Girls in STEM through Roles Models and Mentoring**

Research has shown that having female role models and mentors can help females overcome barriers and succeed in STEM fields (Stout et al., 2011). Thus, recommendation number 4 to build a successful initiative is empowering girls in STEM by ensuring female role models and mentors are included in the program. Moreover, STEM programs with either a peer mentor or adult mentors throughout middle school can improve performance in school and beyond by increasing the likelihood that young women will seek out other successful women in the STEM workforce (Zirkel, 2002). However, because women are underrepresented in STEM, there are fewer female role models and mentors to go around. By partnering with a local university, Gustinelli connects the STEM Girls with female mentors. Mentors join the class as guest speakers and coordinate with the teacher to provide follow-up activities for the girls to work collaboratively with experts on STEM projects.

**Summary**

In summary, the STEM Girls class is an example of an initiative to promote females in STEM that can be directly embedded in the regular school day. The program serves as an example for other institutions looking to close the research-practice gap and provide opportunities for young girls to develop skills in STEM. The class provides a space for girls to explore new identities through STEM, conceptualize future STEM careers, improve their confidence level in successfully conducting STEM activities, and support other students through peer-to-peer mentoring as well as connecting to adult mentors. Meaningful experiences for STEM Girls within the context of the class allow young women to not only improve STEM skills but visualize STEM careers and reach out to professional women in the STEM field. Aspects of the STEM girls’ class can easily be adapted for traditional education settings throughout the school year in other courses and disciplines. Long-term goals of the program include expanding the mentorship aspect and potentially training pre-service educators to act as role models and implementing STEM workshops for educators who teach in various disciplines.
REFERENCES


APPENDIX A

This appendix contains examples of slides describing fun and easy-to-do science experiments created by STEM Girls for the Science Fair and Expo.

Lava Lamp Experiment

Procedure:
1. Fill a clear glass cup 1/3 of the way with water.
2. Fill the rest of the container most of the way up with vegetable oil and all to settle.
3. Add a few drops of your choice of food coloring.
4. Break an alka-seltzer tablet into a few small pieces and drop them into the container one at a time.
5. Watch your lava lamp erupt into activity!

Glitter Germ Science Experiment

Supplies:
Glitter, dish soap, plastic bowls, water

Procedure:
1. Fill a bowl halfway with water.
2. Put as much glitter in the bowl as you wish.
3. Get the dish soap ready.
4. Put your fingers in the dish soap.
5. Take your fingers out and place them in the bowl with the glitter.
6. Observe how the glitter goes to the edges of the bowl.
Breaking Out the Immigrant and Refugee Experience: Integrating Digital Escape Games with Children’s and Young Adult Literature

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Immigration is a global phenomenon and foundational aspect of our shared cultural experience. The global culture is being shaped by “unprecedented demographic shifts,” with immigration becoming a major contributor to population growth (Amthor & Roxas, 2016, p. 155). This displacement is happening globally and locally; it is important for us to support immigrants and refugees as they transition into K–12 classrooms. It is projected that by the year of 2050, one-third of the children in the U.S. will be either immigrants or the children of immigrants (Lander, 2018). It is important for educators to adapt to the dynamics of a multicultural classroom and become culturally responsive to serve the needs of all students, including immigrant and refugee students. One such method is with a digital game-based, problem solving, and immersive experience designed to engage participants in higher-level authentic learning while encouraging teamwork and collaboration toward mutual goals. We will be focusing on this digital game-based, breakout learning as an exercise in empathy designed to connect learners with literature that highlights the immigrant and refugee experience, building toward mutual understanding between native and first-generation Americans.

INTRODUCTION

Historically, immigration has not equaled acceptance or understanding (Khailova, 2018). The future of our global community is being shaped by “unprecedented demographic shifts,” with immigration becoming a major contributor to population growth (Amthor & Roxas, 2016, p. 155). It is projected that by the year of 2050, one-third of the children in the U.S. will be either immigrants or the children of immigrants (Lander, 2018). We as educators should adapt to the dynamics of the multicultural classroom and become culturally responsive to better serve the needs of all students, including immigrant and refugee students.

Immigration is a sometimes controversial, foundational aspect of the American cultural experience. How can we support an inclusive learning environment for all students? Utilizing digital breakout experiences, educators can easily use technology to execute an exercise in empathy designed to connect native-born and first-generation K–12 Americans with quality literature that highlights the immigrant and refugee experience, building toward mutual understanding. An increasingly common experience used in classrooms at all grade levels is the digital breakout experience, an escape-style, educational game where groups of learners must work collaboratively to solve a series of puzzles or problems by unlocking puzzles with clues (Rouse, 2017). It is a game-based, problem solving, and immersive experience designed to engage students in higher-level authentic learning while encouraging teamwork and collaboration toward mutual goals. Integrating digital breakout games and literature that highlights the immigrant and refugee experience has great potential to engage participants in learning to achieve mutual cultural understanding in their classroom.
RESEARCH REVIEW

Digital breakouts are relatively new to K–12 schools and universities (Weisberg et al., 2022). The digital breakout is structured in the traditional game form that contains scenarios, learning objectives, tasks, opportunities to repeat until successful, resolution, and concluding discussion prompts (Kroski, 2020; Weisberg et al., 2022). This digital breakout gamification is learning delivered and disguised as fun and is a vehicle to provide lessons that utilize a myriad of collaborative, critical-thinking and problem-solving skills (Kroski, 2020). Using engagement strategies that are common to games digital breakouts can become immersive experiences that entice learners into experiences outside of their own (Weisberg et al., 2022).

Hwang and colleagues (2012) state that game-based learning can provide an environment that supports knowledge acquisition through game play. These scenarios can then be applied to real-world learning that supports future implementation. The complexity and opportunities for social interaction can provide students with motivational learning engagement. This can lead to increased student learning with focused engagement that can support the acquisition of cultural awareness (Hwang et al., 2012).

The customizable nature of breakout experiences allows for the inclusion of quality literature in the form of eBooks and cross-curricular engagement that can be replicated and shared over digital platforms (Ouvrard-Prettol & Linden, 2018). These types of innovative experiences are heralded as an epic win for game-based learning and helping learners break out of their comfort zones (Detwiler et al., 2018; Guan et al., 2022; Nadolny, 2016). Creating an atmosphere of camaraderie and belonging build shared understanding among all students in a classroom.

IMPLICATIONS

Immigration is as American as apple pie. It is historically a point of national pride, inspiring national nicknames such as ‘Land of the Free’ and ‘the Land of Opportunity.’ Our numbers of immigrants have steadily increased. According to the US Census Bureau, the number of foreign-born individuals currently living in the United States increased, and of those, about 3 million refugees have been resettled in the U.S. since Congress passed the Refugee Act of 1980 (U.S. Census Bureau, 2021). The school student population of immigrants and refugees is surging. However, our historical pride over immigration has the potential to turn to prejudice without shared cultural knowledge and identity.

Native ethnocentrism can be developed when children and young adults only encounter literature that represents themselves. Ethnocentrism creates a view of the world as supportive of only the members of society that are similar in thought, deed, and culture. This perspective allows for the formulation of ideas that focuses on the differences in culture identity and the isolation of the ‘other.’ The cultural identity development of the ‘other’ can be formulated under these circumstances. If the identity of the ‘other’ is formulated without the benefit of visual representation within literature, ideas and visions for the future can be narrow and without imagination (Khailova, 2018).

We are a nation of immigrants and refugees. We are also a nation of immigration restriction. The dichotomy of these statements is not mutually exclusive or surprising. We are, for better or worse, both immigrant-friendly idealism and immigrant-restrictive nativism within the same nation. One generation’s concerns can be directed at an incoming immigrant group. Then decades later, the persecuted immigrant groups’ grandchildren can be leading the battle against the next wave of incoming immigrants. In this way, the cycle of nativism, immigration cultural awareness and eventual understanding continues to evolve, creating an augmented and ever-changing American cultural identity (Schrag, 2010). As educators, the classroom is one obvious place where these concerns can be addressed.

Educators have an opportunity to participate in topical learning related to immigrant and refugee student experiences in America. It is important for both the native and first generation to see technology, multicultural representation in quality children’s and young adult literature to support empathy and emotional understanding. Multicultural representation in children’s and young adult literature is essential. American schools have a mismatch of representation in literature and the student population. Our teachers and literature are predominately representative of the European-American perspectives. The school student population of immigrants and refugees is surging. The likelihood that our classrooms will have diversity in culture and language is on the rise. Multicultural representation in literature can support cultural knowledge acquisition of immigrants and lessen ethnocentrism of natives. Literature can act as a mirror of experience that can validate and add confidence to the learning process. Our school-aged digital native students are a perfectly poised audience to receive the message of empathy and understanding from educators (Khailova, 2018).
How can support of cultural knowledge acquisition by native-born and first-generation Americans in diverse classrooms be facilitated? Teachers can connect with our first generation and native-born Americans using technology, quality children’s and young adult literature that strongly represents the culture and experience of immigrants and refugees coming to America. A few of the myriad of quality literature and multimedia resources that focuses on the immigrant and refugee experience is found in Appendix A, and Appendix B.

However, a greater impact can be reached if more than just the presence or inclusion of literature is utilized. The true magic will happen when technology, high-quality children’s and young adult literature engagement occurs within the context of shared literature-related discussion amid digital breakout game experiences. Quality children’s and young adult literature used to create a digital game-based learning experience focused on digital breakout game experience will provide an educator-monitored environment for group cultural learning and discussion. Our students will be living in a more culturally diverse world that will require an understanding of personal cultural identity, diverse cultural identity perspectives, connecting to the greater good, and recognizing while acting on inequities (Short et al., 2022). The teacher’s task in creating the breakout experience is to create a digital environment, themed to the original text, with the three core elements of the challenge, solution, and reward related to items found in the digital environment (and by extension, the literature).

Connecting cultural discussion with elements of gamification will allow students a format for conversation that mimics the digital escape room concept. Gamification using technology in the classroom can be addressed in myriad ways. The first step in designing a digital breakout room experience that has digital literature appropriate to support an educational focus on the refugee or international experience is to identify the literature that the digital breakout room will be designed around. This can be a specific title, such as any of those mentioned in Appendix A, or depending upon the age of the students in the class, multiple texts or subgenres of literature. The core components of the breakout experience after the identification of the theme are the challenge posted to students, the solution to solving the challenge, and the reward (Wiemker et al., 2015).

In physical breakout rooms, one common theme is for a locked box to require a multi-digit combination to open it. The solution to identify the digits can be found within the room, hidden or otherwise obscured by solving puzzles. Once the digits are identified, the combination can be entered into the lock, which gives the solvers the reward. A digital breakout experience can operate in much the same manner. It is beyond the scope of a single article to potentially list the various ways that such a breakout experience could be created digitally, as the options are as limitless as the imagination of the teacher. However, to provide a starting point for interested educators, an example will be provided.

Suppose, for instance, that the literature was the novel *The Importance of Wings* by Robin Friedman. Within the digital space might be a photograph of Farrah Fawcett from the television show *Charlie’s Angels*, along with photos of several other famous celebrities. The ‘wings’ of the title refer to the feathery hairstyle of Farrah Fawcett, and beneath her photo might be a number or a symbol that the students would need to enter the digital lock to gain access to the reward, which could be anything ranging from an in-class perk to a physical reward to extra credit. Ideally, this would be just one piece of the code needed, as another question could center around additional elements of the plot of *The Importance of Wings*. In this way, interacting with the chosen literature and the themed ‘room’ encourages students to dig deeper into the text, and based upon the questions asked by the teacher during the solution phase, allow learning to occur within this digital gamification environment.

The steps below can support your development of a digital breakout room:

1. The first step in creation is to provide a digital space online to serve as the entry point to the breakout narrative. This entry point is a portal for the participant to the common quizzing platform and could be a shared online document, a teacher-created website, or even a blog post.
2. Next, provide direct access to the challenge on a common platform within the created digital portal online. The technology tool used as the common platform, will be used to build the quizzes. The chosen digital tool as common platform should have the functionality of only allow access when the right answer is entered.
3. Select appropriate literature based on acquired knowledge and participants grade, age, demographics, and cultural focus, which is crucial to establishing a successful breakout game experience. To facilitate ease of incorporation, Appendix A breaks down the materials into book title, author grade level, historical period, and character immigrant generation.
4. This combination of literature and game-based learning can be customized by grade level, culture, and cross-curricular topic to embrace multiple curriculum needs at the K–12 level.
To add to these general steps, Table 1 shows a planning and activity arch in support of the creation of digital breakout.

Table 1

<table>
<thead>
<tr>
<th>What are the steps in planning a Digital Breakout?</th>
<th>What are the activities in support of these steps to create a Digital Breakout?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose technology platform to house your digital breakout online and provide opening context</td>
<td>Create a digital environment in which inviting learning and reading are enjoyable and can support digital needs</td>
</tr>
<tr>
<td>Get organized: create a form to support your organization and files for multimedia resources</td>
<td>Make sure to have a location to organize and store your digital multimedia. An example could be Google Drive</td>
</tr>
<tr>
<td>Interpret goals for the digital breakout from existing student demographic data</td>
<td>Assess class and community demographics to select the goals for the overall digital breakout</td>
</tr>
<tr>
<td>Choose the background story of supportive high-quality literature</td>
<td>Choose appropriate eBook to be the text to serve as the background story based upon existing student data</td>
</tr>
<tr>
<td>Create the narrative by having a path supported by a theme and demographics that moves you through the experience</td>
<td>It is important to create the path through the narrative that is reflective of the overall class goals and demographics supporting the experience for the player</td>
</tr>
<tr>
<td>Develop student learning outcomes for the digital breakout from existing data</td>
<td>Interpret learning outcomes from the goals for the digital breakout from existing student demographic data</td>
</tr>
<tr>
<td>Select technology tools to best support the chosen learning outcomes</td>
<td>Multiple technology tools can be selected to support the creation of clues to solve number locks, color locks, alphabet/word locks and directional locks</td>
</tr>
<tr>
<td>Build clues using multimedia materials, puzzles and locks from associated multimedia</td>
<td>Digital breakout games have locks to open to solve the game these will be constructed using multimedia materials</td>
</tr>
<tr>
<td>Implement the experience within the digital experience</td>
<td>Make time for the digital breakout to be fully experienced by all students becoming actively involved</td>
</tr>
<tr>
<td>Allow students the opportunity to respond</td>
<td>Make a space for students to engage in discussion about the experience for feedback on the topic, technology usability, and interactivity</td>
</tr>
<tr>
<td>Allow the educator opportunity to reflect</td>
<td>Make a space for the educator to engage in reflection about the experience, topic, technology usability and interactivity</td>
</tr>
<tr>
<td>Educator revises based upon response and reflection</td>
<td>Start with a reconsideration of the steps and information attained at each point with a mind toward improvement</td>
</tr>
</tbody>
</table>

This digital breakout experience could even be done collaboratively in real-time during class, with the teacher providing clues that have digital aspects and fostering discussion as they progress through the eBook. In addition to the research that shows the effectiveness and academic benefits of these digital breakout experiences for students, the benefits for the refugee and immigrant experience can also be profound in the hands of the right educator (Fernandez-Portero & Castillo, 2022). Technology, gamification, and breakout experiences coupled with quality literature focused on the immigrant and refugee experience, facilitated by an educator can be a path toward shared understanding and respect in our diverse classrooms.
REFERENCES


ADDITIONAL READINGS


# APPENDIX A

## Chart of Texts in Detail

<table>
<thead>
<tr>
<th>Culture</th>
<th>Book Title</th>
<th>Author</th>
<th>Grade Level</th>
<th>Historical Period</th>
<th>Character Immigrant Generation</th>
<th>Publisher</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>My Name is Sangoel</em></td>
<td>Williams, Karen Lynn; Mohammed, Khadra</td>
<td>PreK–2</td>
<td>1970s to Current</td>
<td>First</td>
<td>Eerdmans Books for Young Readers (2009)</td>
</tr>
<tr>
<td></td>
<td><em>The Orange Houses</em></td>
<td>Griffin, Paul</td>
<td>Grades 9–12</td>
<td>1970s to Current</td>
<td>First</td>
<td>Dial Books (2009)</td>
</tr>
<tr>
<td>Asian Culture</td>
<td><em>Bringing Asha Home</em></td>
<td>Krishnaswami, Uma</td>
<td>Grade 3–5</td>
<td>1970s to Current</td>
<td>All</td>
<td>Lee &amp; Low Books (2006)</td>
</tr>
<tr>
<td></td>
<td><em>Dogtag Summer</em></td>
<td>Partridge, Elizabeth</td>
<td>Grades 6–8</td>
<td>1970s to Current</td>
<td>First</td>
<td>Bloomsbury Books for Young Readers (2011)</td>
</tr>
<tr>
<td></td>
<td><em>Gateway</em></td>
<td>Shinn, Sharon</td>
<td>Grades 6–8, Grades 9–12</td>
<td>1970s to Current</td>
<td>First</td>
<td>Viking (2009)</td>
</tr>
<tr>
<td></td>
<td><em>How I Became an American</em></td>
<td>Gündisch, Karin</td>
<td>Grades 3–5, Grades 6–8</td>
<td>Turn of the Century</td>
<td>First</td>
<td>Cricket Books (2001)</td>
</tr>
<tr>
<td></td>
<td><em>Call Me Ruth</em></td>
<td>Sachs, Marilyn</td>
<td>Grades 3–5, Grades 6–8</td>
<td>Turn of the Century</td>
<td>First</td>
<td>Doubleday (1982)</td>
</tr>
<tr>
<td></td>
<td><em>Pick &amp; Shovel Poet: The Journeys of Pascal D’Angelo</em></td>
<td>Murphy, Jim</td>
<td>Grades 6–8, Grades 9–12</td>
<td>Turn of the Century</td>
<td>First</td>
<td>Clarion Books (2000)</td>
</tr>
<tr>
<td></td>
<td><em>Uprising</em></td>
<td>Haddix, Margaret Peterson</td>
<td>Grades 6–8, Grades 9–12</td>
<td>Turn of the Century</td>
<td>First</td>
<td>Simon &amp; Schuster Books for Young Readers (2007)</td>
</tr>
<tr>
<td>Culture</td>
<td>Book Title</td>
<td>Author</td>
<td>Grade Level</td>
<td>Historical Period</td>
<td>Character Immigrant Generation</td>
<td>Publisher</td>
</tr>
<tr>
<td>---------------------</td>
<td>----------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>----------------------</td>
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<td>-----------------------------------</td>
</tr>
<tr>
<td></td>
<td>Cool Salsa: Bilingual Poems on Growing up Latino in the United States</td>
<td>Carlson, Lori M</td>
<td>Grades 6–8 Grades 9–12</td>
<td>1970s to Current</td>
<td>All</td>
<td>Square Fish (2013)</td>
</tr>
<tr>
<td></td>
<td>Esperanza Rising</td>
<td>Ryan, Pam Muñoz</td>
<td>Grades 6–8 Grades 9–12</td>
<td>WWI to WWII</td>
<td>First</td>
<td>Scholastic Press (2000)</td>
</tr>
<tr>
<td>Middle Eastern Culture</td>
<td>Azzi in Between</td>
<td>Garland, Sarah</td>
<td>PreK–2 Grades 3-5</td>
<td>1970s to Current</td>
<td>First</td>
<td>Frances Lincoln Children’s Books (2012)</td>
</tr>
<tr>
<td></td>
<td>The Importance of Wings</td>
<td>Friedman, Robin</td>
<td>Grades 3–5 Grades 6–8</td>
<td>1970s to Current</td>
<td>First</td>
<td>Charlesbridge (2009)</td>
</tr>
</tbody>
</table>

*Note: Book information in this table is generated from [https://library.niu.edu/ulib/projects/stories/books.html](https://library.niu.edu/ulib/projects/stories/books.html)*
APPENDIX B

Multimedia Resources

Breakout EDU game resources
Game examples: https://platform.breakoutedu.com/
Game design tutorials: https://www.breakoutedu.com/designvideos
Resources for building puzzles: https://www.breakoutedu.com/puzzleresources

Example Digital Breakout Rooms
Free Virtual Escape Rooms for Schools

Resources for Creating Digital Breakout Rooms
Google Account Creation: https://accounts.google.com
Google Workspace Dashboard: https://workspace.google.com/u/1/dashboard
YouTube Tutorials for Creating Digital Breakout Room in Google Tools:
https://www.youtube.com/watch?v=p-4LvbAHA9c
https://www.youtube.com/watch?v=QyBbyCMqXVw
ARTIFICIAL INTELLIGENCE
Helping PreK–12 Teachers Overcome the Fear of Artificial Intelligence

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Artificial intelligence (AI) in general, and AI-based chatbots (e.g., ChatGPT, Bing Chat) and search engines (e.g., Google Bard) in particular, have received significant attention in mainstream media recently. This is partly due to the recent availability and ease of use of such technologies. This is also due to ethical concerns raised by school administrators and teachers about the potential use and misuse of AI in education. For instance, rampant concerns range from students cheating to teachers being replaced by AI-based instructors. This fear has led many districts, and even some countries, to ban either the broad use of AI-based tools or the specific use of certain tools like ChatGPT. While there are potential concerns, as there are with any technology, there is also significant and potential promise. Unfortunately, the fears felt by teachers internally or placed on them externally may limit their interest or ability to understand, try out, and potentially employ AI for their own teaching or their students’ learning. The purpose of this chapter is to specifically highlight pros and cons of using various AI tools for preK–12 instruction. The chapter includes specific instructions for teachers interested in professional development and classroom integration.

INTRODUCTION

Artificial intelligence (AI) can be defined as both “a branch of computer science dealing with the simulation of intelligent behavior in computers” and “the capability of a machine to imitate intelligent human behavior” (Merriam-Webster, 2019, n.p.). While it has been around for decades, it has received significant recent attention in mainstream media (Pecarelli, 2022). It has also received prominent—and somewhat negative—attention in educational communities. New York City schools, for instance, made headlines in early 2023 by becoming the first school district to ban ChatGPT (an AI-based chatbot; Yang, 2023). Other schools and even other countries followed suit (Martindale, 2023).

Such widespread attention has caused educators to ponder if and how AI is going to impact education. While opinions vary, Dan Fitzpatrick (2023) may have it right when he suggested that “AI won’t replace teachers, but it will replace teachers who don’t use AI” (n.p.). The challenge is that the bans, along with anxiety spreading around concerns like cheating or the replacement of teachers, have created a sense of fear for teachers. It has limited many teachers from understanding what it is, its pros and cons, and its potential long-term impact on the field (i.e., Naumova, 2023).

The purpose of this chapter is to specifically address various AI-based tools. While there are concerns, ethical decisions, and dangers that must be addressed, there is enough research highlighting the promise of the technology to warrant teacher (and school administrators and technology coordinators) investigation. The remainder of this chapter provides an overview of the existing research as well as implementation steps for teachers who want to use it for professional use or for student instructional work.
RESEARCH REVIEW

AI has a long and storied research past with education writ large. This has included scholarship on various topics such as human interaction with AI (e.g., Blut et al., 2021; Kaplan et al., 2023) and specific investigations into content areas like medicine (e.g., Visaggi et al., 2022), design (e.g., Yang et al., 2020), and computer science (e.g., Barnes et al., 2017).

Its exact role in preK–12 education depends largely on the application of AI. For instance, if considered broadly, adaptive testing could be considered AI that has been well researched (e.g., Conejo et al., 2004). A recent special issue of the Journal of Research on Technology in Education provided multiple articles with evidence to suggest that AI has both affordances and constraints (Ifenthaler & Schumacher, 2023). In other words, like all educational technologies, the implementation strategies surrounding its use, particularly given those affordances and constraints, take precedence (Ferdig, 2006). However, there is scholarly evidence that AI technologies can significantly and positively impact K–12 education, particularly in terms of learning achievement (Kandlhofer et al., 2016; Zheng et al., 2021).

Defining AI more specifically to address current topics like chatbots (Nayak et al., 2023; Wu et al., 2020), deepfakes (Kietzmann et al., 2020), and AI-based image generation (Ferdig et al., 2023), there are fewer research studies available directly related to preK–12. Many of the scholarly articles are explanatory or theoretical (e.g., Collins, 2023; Zhai, 2023). However, even with minimal studies and ethical issues to be resolved, authors consistently point to research (including K–12 education, higher education, and from other fields) that shows the promise of AI for improving teacher workload, positively impacting student performance and motivation, knowledge consolidation, and enhancing teacher-student learning relationships (Adiguzel et al., 2023; Chiu et al., 2023; Xia et al., 2023).

IMPLICATIONS

Preparing to use AI

In order to effectively use AI in support of and integrated within the classroom, it is important that educators become familiar with the capabilities of AI, what is and is not available to them within their districts, and how to effectively utilize these tools to support teaching and learning. As with any novel technology, the gap between expectations and reality is very real, generating fear that drives preventative policies that can stifle learning opportunities. However, educators that engage with the process of learning how to use AI tools can integrate their use to positively impact learning by following six steps:

1. Getting familiar with AI
2. Understanding AI-related prompts
3. Becoming proficient with AI
4. Seeking resources about AI
5. Exploring pros and cons in using AI for education
6. (or 1) Checking with school district IT department/administration

The first step to using any AI tool (including chatbots) is to use them to start building personal familiarity with their capabilities and functions. Educators can begin by creating a personal account with a simple AI Chatbot like ChatGPT, Google Bard, or Bing Chat. The good news is that these chatbots have very low learning barriers and can be easily used without any prior training. By simply asking questions, and letting curiosity guide the process, even new users quickly discover capabilities and limitations that will positively (or negatively) impact their work.

A second important step is to understand the role of prompts. Regardless of whether it is AI-based image generation or an AI chatbot, entering prompts “is how a user communicates with AI tools. With prompts, you can ‘tell’ the AI what you want and how you want it to be done. Through a prompt, you’re basically describing what you want to see as a result” (Mileva, 2023, n.p.). Educators can discover new ways to unlock the power of AI chatbots by learning how to effectively prompt. Learn Prompting has developed a free website that provides step-by-step guidelines on how to prompt chatbots effectively in order to get accurate and useful responses.
The next step is to begin building familiarity with the variety of AI tools that are available and their corresponding functions. This will help educators begin to discover possible ways that AI can support and enhance their work. While AI Chatbots like ChatGPT and Google Bard are the most popular AI tools, there are many new AI tools that are being developed every day with a wide variety of functions. For example, Midjourney, StarryAI, and Dall-E 2 use AI to generate original artistic and graphic works based on user inputs. Additionally, tools like Curipod, Slidesgo, Beautiful.ai capitalize on AI to generate slide decks for presentations based on user inputs. Soon, Microsoft Copilot and Google Generative AI promise to integrate many of these capabilities in their full productivity app suites.

With the landscape of AI constantly changing, Futurepedia has developed a useful website that has a large AI Tools directory. It is updated daily and is easily filtered to narrow in on preferred functions. In short, if there is a task that could be enhanced with AI, it likely already exists or will exist soon. By exploring the wide variety of AI Tools available for personal, professional, and educational use, educators will be able to begin brainstorming ways to use AI tools to enhance their work as an educator.

Once a teacher has decided to use an AI tool, a fourth important step is to search for existing resources that clearly describe capabilities and limitations. For example, Trust (2023) has developed an essential overview of the capabilities, limitations, and possible uses for ChatGPT in education. Foley (2022) has developed a useful guide on AI image generation. And Preface (2023) produced a useful guide on AI for kids.

A fifth step, and an important caveat, is to understand that AI has tremendous promises and pitfalls. Not everything that is created by AI is perfect. For instance, the following prompt can be entered in ChatGPT:

Write a possible list of reasons why teachers would need to create images. Provide references and websites to support each reason. Write at least 25 reasons. Provide a reference list at the end.

ChatGPT will respond with 25 items and a reference list (either at the end or for each item). In the iteration run for this chapter, none of the links worked. In a second iteration using Bing Chat, some of the links worked, but they were not related to the content addressed. Multiple discussions on Reddit have users finding similar outcomes where bots create false citations (e.g., Javacafe, 2023). In short, caution is necessary when receiving AI responses.

The final step for preparing to use AI tools is for educators to check with their district IT department and/or administration on their current policies for AI in the classroom. This will help ensure access as well as making sure that the planned use is consistent with school policy. This final step could have arguably been the first step. In other words, it might be best to check with IT staff before learning whether certain tools are banned for student use. However, this step was kept last because of the fast-moving nature of AI innovation. Many schools have yet to develop a policy around the use of AI in the classroom. In such cases, innovative educators can be collaborative partners to discover the right guardrails to facilitate learning and avoid potential pitfalls (see Adams et al., 2021; Miller, 2023). But this collaborative engagement around policy would be more successful with initial teacher exploration of such tools.

**Using AI technologies for teacher work**

AI tools can provide powerful assistance to educators that can make their classrooms more efficient and impactful. Several examples of how teachers might use AI tools as a support to their work activities are provided below (also see the included appendices).

**Lesson Planning.** Every educator has experienced a lesson plan block where they know their lesson is not effective, but they cannot seem to develop a new iteration of the lesson that better meets the needs of their students. With an AI chatbot like ChatGPT or Google Bard, a teacher can prompt the chatbot to develop a customized lesson plan by following simple steps.

1. **Prompt:** Ask the AI chatbot to develop a lesson plan. In the prompt, give the chatbot the criteria for the lesson, including objectives, the grade level of students, the types of activities they are looking for, and the time limitations.
2. **Enhance:** The chatbot will generate a step-by-step lesson plan. Carefully read over the lesson plan to identify areas that can be improved. Prompt the chatbot to enhance portions of the lesson. For example, an educator might prompt the chatbot to replace a lecture for one portion of the lesson with a group activity. To get additional full lesson options, teachers can click “Regenerate” or “Try Again.”
3. **Edit:** Educators should then carefully edit with their own educational expertise. Chatbots have limitations that can only be accounted for by human educators. For example, chatbots are unlikely to be able to correctly identify the length of time an activity will take or the resources that are (or are not) available to a teacher to complete an activity. Furthermore, content expertise is needed by the educator as AI chatbots could potentially be imprecise with the content that needs to be taught and how it should be scaffolded.

**Slides development.** Developing visual aids that are engaging to students is a time-consuming and error prone process. AI tools have been developed that can generate slides based on educational topics and objectives. *Curipod* offers an AI slide generating tool to build interactive slides that can increase engagement. Here are some recommended steps.

1. Create a *Curipod* account and click “Create lesson.”
2. Choose the type of lesson to create. “Full Lesson” will create the lecture and interactive slides.
3. Type in a specific prompt for the topic of the lesson. The more specific the topic, the better the slide deck will be. Click the dropdown arrow to paste in learning objectives.
4. Click “Do Magic”
5. Edit: Carefully edit the slides based on educational expertise. Slide generating AI tools have limitations that require a human educator to correct. For example, AI slides tend to have full sentences rather than bullet points and tend to have few images or a disconnect between images and text. Read carefully to ensure that the content is correct as AI can generate imprecise content at times.

**Student Feedback:** Educators can use AI chatbots like *ChatGPT* or *Bing Chat* to provide objective feedback on student work using the following steps.

1. **Prompt:** Ask the chatbot to give student feedback on a written text using the criteria that is outlined in the rubric. Number the criteria so that the feedback will come back in an organized format. Paste in the student work following the criteria.
2. **Enhance:** In just a few seconds, the AI chatbot will generate feedback based on the prompt. This feedback will be explanatory in nature and provide recommendations for improvement. Chatbots are prone to make some mistakes, so make sure to carefully edit the feedback with educational expertise. Feedback can be regenerated completely or enhanced by choosing a smaller amount of text and prompting more specific feedback on a single criteria.
3. **Personalize:** There is no true substitute for personalized feedback. Reading student work is key to understanding how to adapt practice in the classroom. AI feedback should only be an assistant to student feedback, not a replacement.

**Using AI technologies for student work**

AI assisted work is the future of education and the future of the workforce. As such, the real potential for AI tools is unlocked when they are placed in the hands of students. It is helpful to think of AI tools as having the potential to make menial, time-consuming tasks much more efficient which can open up opportunities for deeper learning in the classroom.

Prior to giving students access to AI, it is important to collaborate with the district IT and/or administration to ensure that the right guardrails are in place. Educators should clearly outline in their syllabi what the appropriate use of AI tools is in their classroom and what specifically constitutes academic dishonesty. AI tools for checking for academic dishonesty like *Turnitin*, *Plagiarisma*, and *SearchEngineReports* should be in place in order to discourage the inappropriate use of AI tools (see Appendix B for various websites that also provide lists of AI cheat detectors). The possibilities for enhancing student learning with AI are endless, but here are a few examples of how AI tools could be used in the classroom to promote deep learning.

**Peer/AI Editor**

1. **Use Case:** Educators have used peer-reviews for decades in order to give students feedback on their work in an efficient manner. However, peer editing is time consuming and difficult to control for quality. Using AI chatbots, a student can input their essay and prompt the bot for feedback based on the criteria provided by their teacher. Within a few seconds, the chatbot will give itemized feedback with recommendations for improvement that can
immediately be applied to improve the written text. Additionally, ambitious teachers that want to teach editing skills can do so by having students edit and enhance AI written essays.

2. **Caution:** Be sure to have clarity on the process for using AI feedback. Teachers should have a very clear policy on what constitutes academic dishonesty with these tasks.

### Problem Based Learning

1. **Use Case:** Most educators agree that the positive impact of problem-based learning (PBL) to develop 21st century skills makes it a preferred instructional model in the classroom. However, one critique of project or problem-based learning is that it simply takes too long. The amount of time that it takes to run a project, along with the variability in student performance, can make it difficult to justify in an educational landscape that requires one to focus on breadth rather than depth. However, AI promises to make many of the steps in the PBL model much more efficient. Collecting best practices, conducting research, developing proposals, and producing slides are all much less time-consuming with the assistance of AI. This means that students can focus on developing solutions, deepening their understanding of the content and how it applies to the problem, and developing their multifaceted solutions. PBL’s will take less time and, as a result, be more likely to fit within the year’s curriculum. Additionally, PBL provides an avenue for building AI tool literacy in students, which is imperative to prepare them for college and career.

2. **Caution:** Be sure to hone what you are grading. Items that were traditionally on PBL rubrics, like developing a slide deck, are less likely to fully represent student learning. Hone your rubric to focus on the skills and content that you wish to measure.

### Create & Analyze

1. There is nothing new under the sun. Every piece of literature, every culture, and every work of art has already been critiqued, analyzed, and rated. However, with AI, brand new works can be generated with the click of a button. A low-shelf way to enhance the classroom is to have students use their understanding of how to analyze culture, critique art, understand philosophy, read a foreign language, or solve a mathematical equation. But instead of using existing work, use an AI tool (e.g., ChatGPT, Bing Chat, or Google Bard) to generate something completely new. Imagine having AI develop an entire new fictional culture and having students predict how long the culture will last based on their understanding of how civilizations have failed in the course of history. Imagine having students critique a new Picasso that was never painted based on what they know about abstract art and the artist in question (using tools like Midjourney, StarryAI, or Dall-E 2). This exercise is a powerful assessment tool that is *cheat proof* and enhances AI tool literacy in students.

2. **Caution:** When students learn how to create in AI, it can lead to future academic dishonesty. Make sure to have clear guardrails for your students and ensure that your school has a system for tracking academic dishonesty when it arises in any classroom.

### REFERENCES


Chiu, T. K., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2023). Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot. *Interactive Learning Environments, 1–17*.


JavaCafe. (2023, March). Fictitious references! Made-up articles! [https://www.reddit.com/r/ChatGPT/comments/124s8se/fictitious_references_madeup_articles/](https://www.reddit.com/r/ChatGPT/comments/124s8se/fictitious_references_madeup_articles/)


Martindale, J. (2023). These are the countries where ChatGPT is currently banned. *Digital Trends.* [https://www.digitaltrends.com/computing/these-countries-chatgpt-banned/](https://www.digitaltrends.com/computing/these-countries-chatgpt-banned/)


Trust, T. (2023, April). ChatGPT & education. Google Docs. [https://docs.google.com/presentation/d/1V09w4fPxrzdWyaYoBpQ3ZdKn325QgDgXsmi0X0/edit?usp=sharing](https://docs.google.com/presentation/d/1V09w4fPxrzdWyaYoBpQ3ZdKn325QgDgXsmi0X0/edit?usp=sharing)


List of Questions for Teachers and Students

One interesting activity for teachers and students is to have them ask the AI questions about itself. Such questions and answers can lead to interesting and important conversations. In other words, it is helpful to get students to move beyond thinking that a) AI is always right and unbiased; and b) AI should only be asked yes/no or one word answers. The example below includes prompts and responses for Bing Chat, but the activity could be used on any AI chatbot.

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Answer provided by Bing Chat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Should I trust AI-based chatbots?</td>
<td>AI-based chatbots can be trusted to provide accurate and helpful information, but it’s important to remember that they are not perfect and can make mistakes. It’s also important to consider potential risks like incorrect or inappropriate responses, data privacy and security concerns, and bias and discrimination. However, if you can fine-tune your prompts and use AI systems responsibly, they can be a powerful tool for learning and education. Ultimately, it’s up to you to decide whether or not you trust AI-based chatbots. I hope this helps!</td>
</tr>
<tr>
<td>Is Bing Chat always right?</td>
<td>Bing is a search engine that provides search results based on the user’s query. While Bing tries to provide accurate and relevant results, it is not always right. The accuracy of the results depends on the quality of the query and the information available on the internet. If you have any specific questions or concerns, I can try to help you find the answer.</td>
</tr>
<tr>
<td>Why should I use Bing Chat?</td>
<td>Bing Chat can help you with a wide range of topics and questions. You can ask for information on any topic, get help with homework or research, find out about the latest news and events, or just chat about anything that interests you. Bing Chat is designed to be engaging, informative, and helpful, and it can provide you with a wealth of information and ideas that you might not have thought of otherwise. Give it a try and see what you think!</td>
</tr>
<tr>
<td>Do you have any evidence of the educational value of Bing Chat?</td>
<td>Bing Chat is a great tool for learning and education. It can help you with homework and research, provide you with information on any topic, and give you ideas and inspiration for your studies. Bing Chat is designed to be engaging and informative, and it can provide you with a wealth of information that can help you learn and grow. While there is no direct evidence of the educational value of Bing Chat, it has been shown to be a useful tool for students and learners of all ages. Give it a try and see how it can help you!</td>
</tr>
</tbody>
</table>
### APPENDIX B

#### Additional Popular Press Reading Lists for Educators

<table>
<thead>
<tr>
<th>AI-text tool</th>
<th>Article’s focus</th>
<th>Article’s URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Bard</td>
<td>To provide an overview for teachers and educators in general about the tool.</td>
<td><a href="https://www.controlaltachieve.com/2023/04/google-bard-overview-for-educators.html">https://www.controlaltachieve.com/2023/04/google-bard-overview-for-educators.html</a></td>
</tr>
<tr>
<td></td>
<td>To highlight the importance of this tool in the current AI landscape with a focus on learning and instruction</td>
<td><a href="https://www.techlearning.com/news/what-is-google-bard-the-chatgpt-competitor-explained-for-educators">https://www.techlearning.com/news/what-is-google-bard-the-chatgpt-competitor-explained-for-educators</a></td>
</tr>
<tr>
<td></td>
<td>To discuss the value of this tool in the context of global education.</td>
<td><a href="https://ts2.space/en/google-bard-the-future-of-global-education/">https://ts2.space/en/google-bard-the-future-of-global-education/</a></td>
</tr>
<tr>
<td>ChatGPT</td>
<td>To describe educational implications of this tool for educators</td>
<td><a href="https://docs.google.com/presentation/d/1V09w4ftPx-rizdWy-aYoB-pQ3DzK1n325OgDgXsnt0X0/edit?usp=sharing">https://docs.google.com/presentation/d/1V09w4ftPx-rizdWy-aYoB-pQ3DzK1n325OgDgXsnt0X0/edit?usp=sharing</a></td>
</tr>
<tr>
<td></td>
<td>To promote time-saving benefits related to this tool in teaching routines</td>
<td><a href="https://www.edutopia.org/article/6-ways-chatgpt-save-teachers-time/">https://www.edutopia.org/article/6-ways-chatgpt-save-teachers-time/</a></td>
</tr>
<tr>
<td></td>
<td>To learn how to use the tool.</td>
<td><a href="https://www.digitaltrends.com/computing/how-to-use-microsoft-chatgpt-bing-edge/">https://www.digitaltrends.com/computing/how-to-use-microsoft-chatgpt-bing-edge/</a></td>
</tr>
<tr>
<td></td>
<td>To discuss why this tool is different from its competitors.</td>
<td><a href="https://www.zdnet.com/article/how-to-use-the-new-bing-and-how-its-different-from-chatgpt/">https://www.zdnet.com/article/how-to-use-the-new-bing-and-how-its-different-from-chatgpt/</a></td>
</tr>
<tr>
<td></td>
<td>5 “Best” AI Content Detection Tools (May 2023)</td>
<td><a href="https://www.unite.ai/best-ai-content-detectors/">https://www.unite.ai/best-ai-content-detectors/</a></td>
</tr>
<tr>
<td></td>
<td>5 Ways to Detect Text Written by ChatGPT and Other AI Tools</td>
<td><a href="https://www.pcmag.com/how-to/how-to-detect-chatgpt-written-text">https://www.pcmag.com/how-to/how-to-detect-chatgpt-written-text</a></td>
</tr>
</tbody>
</table>
APPENDIX C

Additional Scholarly Articles for Educators


The PreK–12 Educational Benefits of AI-Based Image Generation

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Artificial intelligence (AI) has been around since at least the middle of the 20th century; it has been around theoretically much longer than that. However, recent advancements in both the technology and the availability of AI-based tools have brought the topic to the forefront of conversations across academic, personal, government, and professional domains. Much of this attention has been focused on chat-based search engines like ChatGPT, Google Bard, or Bing Chat. Less attention, particularly in education, has been paid to other AI-based technological advancements (e.g., deep fakes, AI-based image generation). AI-based image generation provides a simple way for users, both with and without artistic abilities, to create never-before seen images using simple prompts, keywords, or even lengthy narratives. These images can then be used for a variety of educational, commercial, and personal goals. The purpose of this chapter is to introduce the potential of AI-based image generation to support teaching and learning in preK–12 schools. Research backing image generation is discussed; theoretical support is also provided. The majority of the chapter is then dedicated to providing teachers with straightforward implications to begin integrating image-generation in multiple educational contexts.

INTRODUCTION

Artificial intelligence technology has been around since the middle of the 20th century (Haenlein & Kaplan, 2019). One could argue, however, that it has been around (at least theoretically) for centuries (Sharkey & Sharkey, 2006). It has enjoyed significant recent attention, though, due in part to both advancements in AI (e.g., Alam, 2022) and the accessibility of tools to access AI (e.g., Devagiri et al., 2022).

This attention, particularly for education, has been both positive and negative. For instance, some believe that AI will help make content relevant for students, will help better prepare students, and will help students learn both soft and hard skills (Langreo, 2023). Others worry that it will lead to cheating and dishonesty (Hulick, 2023). This has led to some schools, colleges, and even entire countries banning certain uses of AI (e.g., Castillo, 2023; Scroxton, 2023).

Most of the focus on AI has been placed on chat-based tools (e.g., search engines or chat bots) like ChatGPT, Google Bard, and Bing Chat. There are positive outcomes that are possible with such tools (e.g., Crescenzi-Lanna, 2023; Deng & Yu, 2023). Less attention, however, has been paid to the educational promise of other AI technologies such as image generation. AI-based image generation is simply the opportunity to use AI to create never-before-seen images from prompts entered by a student or teacher. These images can be realistic or cartoon-like; an example of a student prompt (discussing the impact of COVID) and a resulting image from Midjourney is provided in Figure 1 (note that Midjourney returns 4 images in 1). The purpose of this chapter is to demonstrate ways to thoughtfully implement AI-based image generation in the classroom.
RESEARCH REVIEW

There are two areas of research that need to be addressed when understanding the importance of AI-based image generation. The first focuses on the use of images for teaching and learning, with or without technology. Scholarly research has been written that has summarized entire decades of research (meta-analyses) on the use of pictures and images across multiple tools, genres, grades, and content levels (e.g., Christensen, 2006; Cook, 1980; Höfﬂer & Leutner, 2007; Readence & Moore, 1981). In short, while it is not fool-proof, images, pictures, and art can successfully be used to teach preK–12 learners across content areas ranging from economics to literacy and from math to social studies.

A second area of research is any study on the use of AI-based image generation for education. While there is research on the use of AI for preK–12 (e.g., Chen et al., 2020), given the relative novelty of the topic and the tools used to create images, there is not a lot of evidence on its use in preK–12 teaching and learning. Most of the work has been done in areas like computer science (Oppenlaender, 2022), medicine (Matsubara et al., 2022), and fashion (Yan et al., 2022).

One group of researchers had students in preK–12 discuss COVID-related emotions (Baumgartner et al., in review). They used their prompts to create and then reﬂect on images related to their feelings (also see Ferdig et al., 2023; Reed et al., in review). The researchers found that the process led to student learning about AI as well as the ability to externalize their emotions (White & Epston, 1990). Another research team used adults (Azuaje et al., 2023), but also found that such images could be used for therapeutic purposes. In sum, research on image generation is still emergent, but early work on AI and past work on image use show promise for future studies and educational practice.

IMPLICATIONS

There are three speciﬁc steps for any teacher interested in using AI-image generation in their classrooms. Those steps include: 1) getting to know the technology; 2) using image-generation for instructional purposes (i.e., student consumption); and 3) integrating AI-based into the curriculum (i.e., student production).
Preparing for AI-based image generation

There are several tools that support user-friendly AI-based image generation; examples include Midjourney, DALL-E 2, DreamStudio, Stable Diffusion XL, StarryAI, and NightCafe. Even though each program has its own features, they all rely on the same mechanism. Namely, the user writes a textual prompt, and the software generates an image from it. It can be argued that Midjourney and DALL-E 2 are currently the most popular AI-based image generation instruments in terms of quality and access.

Midjourney is hosted on the social media platform Discord. Users on Discord subscribe to the Midjourney channel, they input their prompts in dedicated chat rooms, and then a bot will create images. There are multiple subscriptions levels (from freemium to premium) that differ in terms of number of images that can be generated per month, types of chat that can be accessed on Discord, and features available. A quick start guide of Midjourney is a great place to begin (Midjourney, 2023a). Educators should take note that Midjourney has a PG-13 moderation system in place; more information can be found in the official Community Guidelines page (Midjourney, 2023b).

DALL-E 2 works in a similar way with different licenses available, but it has its own online platform. After creating an account, users write their prompts and then have their images visualized. A complete overview of how DALL-E 2 works can be found here (Foley, 2023).

It can be argued that Midjourney has the best quality in terms of images generated, while DALL-E 2 is user-friendly and does not require many steps to be used (including getting access to Discord, which may not be accessible from some schools).

There are several other alternative online AI art generators that might be worth exploring based on the needs and preferences of the educator. For example, StarryAI might be a good alternative due to its simple interface, daily free credits, and editing features. A guide for beginners of StarryAI can be found here (StarryAI, 2023).

No matter the tool chosen, writing prompts is the most important action in using AI-generated tools (including image, text, or video generation). Prompts are the way users communicate to AI algorithms what they want to have visualized and how. There are at least five common strategies for developing effective prompts (also see Žverkova, 2022).

1. The more a prompt is specific, the better. It is important to add enough details so AI-generated programs can interpret and process the user’s request effectively and with all the desired components.
2. Writing good prompts is a trial-and-error process. It may take multiple attempts and different words or sentences to generate an image that satisfies users’ needs. The revision process can be a good learning tool for both teachers and students.
3. It is important to focus on the how and not only on the what. Indeed, an object (e.g., an animal, an individual) can be visualized in several ways (e.g., cartoonish, realistic, different art styles). Prompts should include these details (some programs also have filters in this regard).
4. Each tool has its own set of rules and requirements, and it is important to keep them in mind. Getting to know various tools is important in both choosing the right tool and using the given tool in the right way.
5. Prompt design is based on understanding how AI understands users’ instructions. Therefore, it is preferable to avoid grammar choices like word repetition and negative terms (e.g., etc.) in prompting because AI may struggle in interpreting them (for more information, see Monigatti, 2022).

A final and important (first or final) step in thinking about all AI tools is to have conversations with school administrators and IT coordinators. Many schools are banning or limiting AI use, which may impact image (or text) generation for teachers and/or students. It should also be noted that some of the risks related to text-based AI (e.g., plagiarism) may apply differently (to a greater or less extent) to image-based AI. At the same time, tools like Midjourney rely on social media platforms like Discord that should be monitored and supervised at the school level. Moreover, not all image generation tools have filters for language or content (Midjourney does have a limited one). Students may see images that are inappropriate for their age or maturity levels. This is a concern that has to be addressed in the classroom and as a field. Regardless, this software can play an important role in supporting instructional practices in classrooms and even for learning activities at home.
Teacher production of images

AI-based image generation has many educational benefits. First, teachers can produce high-quality images at no or low cost for their instructional activities without relying on what is currently available. The versatility of these tools can cover any content area and grade, and AI-generated images are often copyright free. These traits mitigate several issues regarding image search (Hall, 2013).

Second, teachers can personalize the visual content according to their instructional goals and needs. This is an important advantage that empowers educators and their autonomy in designing and developing learning materials and activities. Third, and as a consequence, teachers can reevaluate the adoption of image use or image generation in a variety of instructional activities. For instance, they can implement visual storytelling in their lectures more effectively and even add details to gain students’ attention. This could include having AI generate realistic images of a given historical period, using multiple visual filters to showcase different art styles. Educators can also develop images that are more aligned to their learning audience. For instance, they could create images where the leading protagonists have the same ethnicity or gender as the students being taught.

Finally, teachers can solicit student feedback about a topic (e.g., environmental concerns), use AI to generate images, and then have students use those images as prompts for reflection. The same approach can be followed for addressing soft skills (e.g., empathy, leadership), health (e.g., substance abuse, healthy diet), and socio-emotional learning (e.g., feelings, depression).

Bing Chat was used to generate additional lists of teacher use of images, which can be found in Appendix A (with links). However, two specific instructional examples of classroom activities based on AI-generated images follow.

Teacher example #1: Deploying DALL-E2 to fight bullying

1) Teachers ask students to provide 3 to 5 keywords related to bullying, referring to personal experiences and possible solutions.
2) Teachers select 6 common keywords or significant quotes about personal experiences and another 7 regarding solutions.
3) Teachers use each group of keywords or sentences as a prompt to generate images with DALL-E2. Figures 2 includes two examples.
4) Teachers use the AI-generated images as triggers to discuss bullying in class. Initial prompts may include “how does this image make you feel? Do you think this image represents your feelings or thoughts about bullying?”.

This exercise will provide an opportunity for teachers to address sensitive topics and help students visualize their own feelings and thoughts. At the same time, it will help students understand they share similar emotions with their peers.

Teacher example #2: Deploying to Midjourney to explore literature

A literature or language arts teacher can use Midjourney to generate evocative visuals regarding a novel. For instance, the Divine Comedy by Dante Alighieri is divided into three main parts: Hell, Purgatory, and Heaven. Educators can access this platform and use prompts like Dante Alighieri Virgil Divine Comedy Descending to Hell to produce a cover for a lesson about any of the parts or the characters. Figure 3 includes images created for different parts of this novel. Teachers can use them to make their lectures more captivating but also to focus on specific aspects of the subject (e.g., dualism in the purgatory image). (Note that Midjourney returns four images for every prompt.)
Figure 2

*Images regarding emotions generated with DALL-E 2*

Note: The image on the left was created with the prompt: *anxiety, hopeless, fear, isolation, sadness, void;* the one on the right with the prompt *people helping each other.*

Figure 3

*Divine Comedy related AI images created with Midjourney*

Note. The image on the left was created with the prompt: “Dante Alighieri Virgil Divine Comedy Descending to Hell.” The one on the right was created using: “Dante Alighieri Virgil Divine Comedy Heaven Light.”
Student production of images

Students can also become creators of AI-based images. All the tools described in this chapter (e.g., Midjourney, Starr.AI) are user-friendly and may easily be learned by young students. This accessibility facilitates student-driven assignments and activities, where learners take the lead and develop their own visual imagery.

Bing Chat was used to generate additional lists of why students would create images (see Appendix B). However, some examples are also provided here that highlight the use of AI for those images. For instance, students may be asked to develop their own visual biography via AI tools with a focus on their memories. They may also engage with programs like Midjourney to visualize their thoughts and ideas about a different culture. They would write down what they think about a foreign country and then use their reflection as a prompt to see their thoughts via AI. This effort may help in shedding light on identities, misconceptions, and shared opinions about different lifestyles and cultural norms. See Figure 4 for an example.

Figure 4
Cultural images generated with Midjourney

![Image of cultural images generated with Midjourney]

Note: The image on the left was created with the prompt “normal life in Japan.” The one on the right with the prompt “normal life in Italy.”

An important aspect to consider is that AI-based image generation is a social and shared process. As such, students should be invited to try different prompts and reflect on the different visual outcomes to refine their ability to master this software. In addition, all these programs have active communities that provide a multitude of examples, best practices, and highlights that can help and inspire new learners. Students therefore can be free to experiment and gather ideas from others. For instance, students could be asked to envision the city of the future. Students can be tasked to develop with Midjourney an image that depicts this idea. They can start with a simple prompt like the most efficient city in the world, which generated the images in Figure 5. Then, they can try different terms and see the different results that occur. For instance, Figure 6 shows the changes to the city by simply adding the word happiest to the previous prompt.

In short, students can change and remix what is created, which will also imply a process of discovery (and self-discovery) that may engage, entertain, and motivate them in the long term. A step-by-step guide to create and remix an image with Midjourney is provided in Appendix C.
Figure 5

The most efficient city in the world created with Midjourney
Figure 6

The happiest and most efficient city in the world created with Midjourney
REFERENCES


APPENDIX A: BING CHAT RESPONSE TO TEACHER IMAGE CREATION

Please note: We originally used ChatGPT to answer prompts in Appendices A & B. ChatGPT returned similar responses that each had references to support the recommendation. However, almost all of the references were incorrect; moreover, the references that were correct did not necessarily include information tied to what was being referenced. Bing Chat is not immune to this issue (see Appendix B references). However, we still considered it useful to include this list, both for further information and as a way to show the relationship between AI text generation and AI image generation.

PROMPT: Write 25 reasons why teachers would use images. Include a list of future readings for people interested in the topic.

RESPONSE:

Here are 25 reasons why teachers would use images:

1. To help students understand complex concepts
2. To make learning more engaging
3. To help students remember information
4. To help students make connections between concepts
5. To help students develop critical thinking skills
6. To help students develop visual literacy skills
7. To help students develop creativity
8. To help students develop problem-solving skills
9. To help students develop communication skills
10. To help students develop collaboration skills
11. To help students develop research skills
12. To help students develop digital literacy skills
13. To help students develop media literacy skills
14. To help students develop cultural literacy skills
15. To help students develop social-emotional learning skills
16. To provide visual aids for lectures and presentations
17. To provide visual aids for discussions and debates
18. To provide visual aids for group work and projects
19. To provide visual aids for assessments and evaluations
20. To provide visual aids for online learning and distance education
21. To provide visual aids for special education and inclusive classrooms
22. To provide visual aids for language learning and ESL classrooms
23. To provide visual aids for STEM education and science classrooms
24. To provide visual aids for history education and social studies classrooms
25. To provide visual aids for art education and art classrooms

Here are some future readings on this topic:
- [Making the Most of Visual Aids](https://www.edutopia.org/article/making-most-visual-aids) by Edutopia
- [Teaching with Images](https://ii.library.jhu.edu/2013/04/19/teaching-with-images/) by Johns Hopkins University
- [5 Smart Ways to Use Digital Images in the Classroom](https://www.teachthought.com/technology/digital-images-classroom/) by TeachThought
- [The Importance of Using Images in Teaching](https://medium.com/@NewSpringAcademy/the-importance-of-using-images-in-teaching-cd3d870e2243) by Medium

I hope this helps! Let me know if you have any other questions.
APPENDIX B: BING CHAT RESPONSE TO STUDENT IMAGE CREATION

PROMPT: Write a possible list of reasons why students would need to create images. Provide references and websites to support each reason. Write at least 25 reasons. Provide a reference list at the end.

RESPONSE:

There are many reasons why students would need to create images. Here are some of them:
1. Boosting memory: Drawing information is a powerful way to boost memory, increasing recall by nearly double¹.
2. Visual learning: Visuals are a powerful aspect of eLearning and create strong impressions and lasting memories in learners².
3. Drive motivation: Visuals are the best bet in scenarios where students find subjects uninteresting and lack motivation².
4. Legally using images online: Students need to learn how to legally use images online³.
5. Creating infographics: Students can create infographics to present data in a visually appealing way².
6. Creating posters: Students can create posters for school projects or presentations².
7. Creating comics: Students can create comics to tell stories or explain concepts².
8. Creating illustrations: Students can create illustrations for books or other publications².
9. Creating animations: Students can create animations to explain concepts or tell stories².
10. Creating videos: Students can create videos for school projects or presentations².
11. Creating digital art: Students can create digital art using various software tools².
12. Creating logos: Students can create logos for school clubs or organizations².
13. Creating diagrams: Students can create diagrams to explain concepts or processes².
14. Creating charts and graphs: Students can create charts and graphs to present data in a visually appealing way².
15. Creating maps: Students can create maps for geography projects or presentations².
16. Creating timelines: Students can create timelines to show events in chronological order².
17. Creating mind maps: Students can create mind maps to organize ideas and concepts².
18. Creating storyboards: Students can create storyboards for films, animations, or videos².
19. Creating photo collages: Students can create photo collages for school projects or presentations².
20. Creating memes: Students can create memes to express ideas or opinions in a humorous way².
21. Creating digital portfolios: Students can create digital portfolios to showcase their work and skills².
22. Developing creativity and imagination skills: Image creation helps students develop creativity and imagination skills by allowing them to express themselves visually¹²³.
23. Enhancing communication skills: Image creation helps students enhance their communication skills by allowing them to convey complex ideas visually¹³.
24. Enhancing critical thinking skills: Image creation helps students enhance their critical thinking skills by allowing them to analyze visual information and make decisions based on it¹³.
25. Enhancing problem-solving skills: Image creation helps students enhance their problem-solving skills by allowing them to find creative solutions visually¹³.

References:
[1] Edutopia - Boosting Students’ Memory Through Drawing
[3] Cult of Pedagogy - Teaching Students to Legally Use Images Online

Source: Conversation with Bing, 4/19/2023
(3) Teaching Students to Legally Use Images Online - Cult of Pedagogy. https://www.cultofpedagogy.com/online-images/.
APPENDIX C: HOW TO CREATE AN IMAGE WITH MIDJOURNEY

1) Click on the Midjourney server on Discord (boat icon) (red square).

2) Click on one of the newcomer rooms (red square).
3) In the chat (bottom of the screen), type /imagine (red square) and then click on the /imagine prompt button (green square) that will appear.

4) Now, type your answers to whatever prompt you used in the chat (red square) and push the Enter button on your keyboard.
5) The *Midjourney* bot will generate an image from your answer and mention you (like the cow in the picture below). You may need to scroll down to find your image due to the presence of other users creating their own!

6) Now, you can go back to step #3 and revise your prompt for generating a different image or write a new one! You will notice that even changing (as well as adding or removing) a few terms in your prompt can have important consequences for your image. Therefore, feel free to experiment with words and sentences to see what works best! An example of how minor word differences can change AI-generated images follows below.

<table>
<thead>
<tr>
<th>Prompt</th>
<th>Visual outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>A realistic overview of Parma, Italy, in the Middle Ages</td>
<td><img src="image" alt="Image of Parma in the Middle Ages" /></td>
</tr>
<tr>
<td>Prompt</td>
<td>Visual outcome</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
</tr>
<tr>
<td>A <strong>hyper realistic</strong> overview of Parma in the Middle-Ages</td>
<td>![Image of hyper realistic Parma]</td>
</tr>
<tr>
<td>An <strong>artistic</strong> overview of Parma in the Middle-Ages</td>
<td>![Image of artistic Parma]</td>
</tr>
</tbody>
</table>
The chatbot has been advanced and used in many fields in recent years. It is evident that by applying this Artificial Intelligence technology to our classroom, we can initiate a project-driven learning process that stimulates student interest and teaches the K–12 educators new tools to stimulate students’ curiosity. It encourages students to develop problem-solving and teamwork skills and fosters creativity and logic. It creates a collaborative learning environment in which students can create an app of their choice in the form of a question/answering system. However, many K–12 educators have not adopted this technology in the classroom due to a lack of computing facilities or state topic constraints. This chapter emphasizes how a chatbot can apply in today’s classroom through a science application: how to build a chatbot that answers interesting questions regarding solar systems using Dialogflow. The aim is to provide an introductory gateway to help educators to bring chatbots into education and their classrooms.

INTRODUCTION

Recent advances in machine learning have made it possible for us to interact with computers naturally. One program that facilitates such interaction is called chatbot. Different experiments have shown that chatbots could be effective in K–12 students’ learning, and more importantly, they provide a human-like companion through daily conversation (Wu et al., 2020). Through parametric, e-learning becomes a necessity and still applies in some areas as a supplement learning or primary tool for education. E-learning allows students to expand their knowledge anytime and anywhere. However, as stated by Wu et al. (2020), e-learning could cause feelings of isolation due to the lack of human-like interaction. Experience shows that chatbot platforms can reduce such isolation through their solid human interface, which makes them like human companions. Therefore, the chatbot can be a fundamental future education resource that engages and attracts students and presents knowledge more brilliantly.

To represent how a chatbot can engage in today’s classrooms, we will emphasize its use in education through an application: how to build a chatbot that answers questions regarding the solar system. Let students in K–12 grade build their chatbot through a project-driven learning process will increase interest in the technology. Chatbot technology goes beyond a simple audio stimulus and allows students to become directly involved, experiencing their design in very tangible, interactive, and expeditious schemes. This approach allows them to experience both the successes and failures of designing working systems versus nonfunctional systems. Students can appreciate both the scale and the scope of the results of their system immediately, which prompts them to become invested in the quality of their design skills and strive to improve their knowledge and creating abilities continually.

RESEARCH REVIEW

Natural Language Processing (NLP) models can instantly translate text from one language to another, respond to text/voice commands or queries, or provide suggestions based on large volumes of data. There are a variety of popular NLP models, such as GPT-3 from OpenAI (https://openai.com/api/), BERT from Google (Devlin et al., 2019), ELMo from the Allen Institute (Peters et al., 2018), Microsoft’s ERNIE, and Google’s Transformer. Chatbots are NLP models which respond to specific queries. By giving a large set of question/answering statements, the machine can learn how to respond to questions the user may ask. Chatbots have a user input interface that accepts voice or text and an output interface that provides answers in text, voice, or avatars. Perhaps the most powerful today’s chatbot is ChatGPT which OpenAI released in 2022 (ChatGPT: Optimizing language models for Dialogue, 2022). It can answer questions and keep...
track of the whole conversation like a human. The conversation could vary from simply defining words to performing complex tasks such as telling stories, providing medical advice, or writing articles, along with potential in numerous other areas with significant potential to positively impact society (Abdullah et al., 2022).

In today’s society, chatbots have applications in almost all fields, including medicine, military, art, business, transportation, agriculture, and education. Compared with traditional systems, they often provide a more efficient, cheaper, faster, available, multilingual, and interactive form of responses (Ganesan et al., 2020). Several studies have shown that Chatbots in education can play a significant positive role in students’ learning success and satisfaction (Dutta, 2017; Kerly et al., 2007; Winkler et al., 2018). A conversational dialogic environment of chatbots can increase the speed of students’ searches and make students feel more supported. Student interactions with the chatbot can also be automatically analyzed. In turn, providing teachers with constant feedback on the student learning progress and identification of barriers to reflect on ways to improve teaching effectiveness. Additionally, applications of chatbots can extend to the university setting. For example, the University of Georgia developed a chatbot to handle student’s posts in a discussion forum in a computer science course, which significantly impacted student learning engagement (Goel et al., 2015).

**IMPLICATIONS**

**Chatbot: Solar System Study Circle**

This section represents a step-by-step process to develop a chatbot that interacts with users to answer exciting facts about solar systems. Research of solar systems is one of the science projects in elementary schools. To develop such a chatbot, we utilize the Dialogflow platform developed by Google. This platform is straightforward to use. It has a user interface-friendly platform for inputting a sample of questions and answers. It also has a conversational user interface and can be integrated into other platforms, such as mobile apps, web applications, and various intelligent devices. Furthermore, Dialogflow can analyze the input of the users in the form of text or voice [URL: https://dialogflow.cloud.google.com/] to generate an appropriate answer.

In this solar application, we will create an agent, a dialogue set that handles the conversation with the end users, which will include teachers and students. This agent runs natural language processing artificial intelligence methods in the background to understand the question or request, then provides appropriate answers. The example provided includes a whole conversation addressing five facts about planets:

1. Which planets/objects have humans visited? Earth and Moon
2. What is the distance from the Sun to Neptune? 4,474,641,676 miles
4. Which planets are solid/rocky? Mercury, Mars, Venus, and Earth
5. Which planets are considered gaseous? Jupiter, Uranus, Saturn, and Neptune

We will create five dialogues for these five facts, which map to five intents in Dialogflow. Using Dialogflow, we can create a high-quality dialogue, which means users can ask questions in many different ways, and the agent can conjecture what users are asking and provide the answer needed. In other words, the user does not need to stick to one fixed question format. The Dialogflow can process and understand these requests, even if these requests are expressed in the natural language in many different ways. For example, consider a user question like «What is the distance from Sun to Neptune?» Many possible ways to ask are:

- “Distance from Sun to Neptune?”
- “How far is it from Sun to Neptune?”
- “How many miles is from Neptune to Sun?”

How are these natural languages understood and interpreted? We do not need to input all of these possible natural language expressions. That would be a long exhaustive list of possible expressions. Instead, we only need to input about five to ten phrases. Dialogflow will recognize all the similar phases from the users and can understand the user appropriately.
Therefore, Dialogflow is “Lifelike conversational AI with state-of-the-art virtual agents.” (https://cloud.google.com/dialogflow).

**Steps to Develop a Chatbot**

**Step 1: Create a Dialogflow ES agent**

**Step 1.1:**

1. Go to the Dialogflow ES Console, which is free to use. (https://cloud.google.com/dialogflow/es/docs/quick/build-agent).
2. If asked, sign in to the Dialogflow Console with your Google account. See the Dialogflow console overview for more information.
3. See a console window shown in Figure 1.

**Figure 1**

*Welcome to Dialogflow*

![Welcome to Dialogflow](image)

**Step 1.2:** Create a New Agent.

There are two ways to create a new agent, as shown in Figure 1. First, there is one blue CREATE AGENT button on the bottom right; click it to create a new agent. Alternatively, click the “+ Create Agent “in the left sidebar menu.

**Step 1.3:** The console window displays after clicking the Create Agent, as shown in Figure 2.
**Step 1.3.1:** As in Figure 3, enter the agent’s name as SolarSystem and click the CREATE button. Note that there is no space allowed in the agent name. In addition, you can edit the default language and default time zone.

After clicking the CREATE button, the CREATE button changed to a WORKING bar showing the progress. See Figure 3 below.

**Figure 3**
*Working screen*
Step 2: Create a Dialogflow Intent

After creating the agent, we see that the console window shows the agent name “SolarSystem” on the left sidebar. In addition, intents and CREATE INTENT buttons are on the console window, as in Figure 4. So now we can start to create and define intents.

Figure 4
Create intent screen

Step 2.1: Customize Default Intents

There are two Default agents: Default Welcome Intent and Default Fallback Intent (see Figure 4). Click on Default Welcome Intent; as shown in Figure 5, you will see two parts; the top one in the red rectangle shows the ten possible expressions of greetings. These ten phrases act as training for users to greet with different expressions. Five general responses show at the bottom, such as “Hi, how are you doing?”
Step 2.1.1: Customize Welcome responses with the Solar Application.

In the Text Responses, we will add to these five responses with our solar greeting, such as: “Welcome to Solar System Study Circle! Excited to know some interesting facts about Solar Systems?” as in Figure 6.
Figure 6

Customize welcome response process

Step 2.1.2: Click on the SAVE button.

Step 2.1.3: Test the Customized Greeting.

On the top right of Figure 6 is an area labeled “Try it now.” Input the greeting to see if the greeting dialogue works appropriately (Figure 7). You will see the conversation shown in Figure 7.

- User: “Hi”
- Response: “Good day! Welcome to Solar System Study Circle! Excited to know some interesting facts about Solar Systems?”
Figure 7

Customized greeting process

**Step 2.1.4:** Add follow-up such as responses to users’ answers “yes” or no. Again, we are going back to the intent. Hover your mouse over the Default Welcome Intent, and “Add follow-up intent” appears in Figure 8.
**Figure 8**

*Adding follow-up intent process*

**Step 2.1.5:** Click on Add follow-up intent; six options are shown in Figure 9. Next, we will work on yes and no options.

**Figure 9**

*Follow-up intent options*
**Step 2.1.6:** If the user answers yes to continue, we will add a corresponding response. Click on yes. “Default Welcome Intent - yes” shows up. See Figure 10.

**Figure 10**
*Default welcome intent – yes screen*

**Step 2.1.7:** Click on Default Welcome Intent -yes, Add the following response in Test Response and click the SAVE button in Figure 11. “Great! Which facts are you interested in? 1) Planets human has visited? 2) Distance from the sun to Neptune? 3) Planets with moons; 4) Solid/rocky planets; 5) Gaseous planets.”

**Figure 11**
*Saving the welcome intent*
**Step 2.1.8:** Click on Default Welcome Intent - no, Add the following response in Test Response, turn on “Set this intent as end of conversation,” and click the SAVE button, Figure 12.

- “Come back to visit the Solar System study circle soon! We will miss you! Bye!”

**Figure 12**

Ending conversation process
Step 2.1.8: Test the customized greeting with yes and no options as shown in Figure 13.

Figure 13
Testing the customized greeting

Step 2.2: Define Intents

For each agent, we can define many intents besides the default intents. All these intents together can handle the whole conversation related to our application. One intent classifies a user’s intention for one conversation turn. During each conversation turn, Dialogflow tries to match the users’ typing or saying to the best intent of our agent. Based on the best matching, the agent gives the best possible responses (Zargham et al., ICFE 2018).

Step 2.2.1: Now we can add our intent; in our case, in Figure 14, we will name it “get-fact1” and click on SAVE. This intent is to interact with the user to answer the first fact about the solar system, like “Which planets have humans visited?”
Figure 14

Naming the intent

Step 2.2.2: Click on ADD TRAINING PHASES to add five to ten possible phrases, in Figure 15, like the following:

- How many planets have humans visited?
- Which planets/objects have humans visited?
- Planets humans have landed on
- 1
- first fact
- distance

After inputting one phrase, type enter key, and another blank prompt will show, and you can continue to enter your training phrase. Here we input the sentence, word, and number to represent different possible ways of users’ input expression.
Step 2.2.3: Type in the Text Response in Figure 15: “There are two planets humans have visited: Moon and Earth. Great! Any more facts you are interested in? 1) Planets human has visited? 2) Distance from the sun to Neptune? 3) Planets with moons; 4) Solid/rocky planets; 5) Gaseous planets.”

Figure 15

Adding a text response
Step 2.2.4: Test it on the right-hand side of the console; see Figure 16. Here I am asking, “Show me the first fact,” which is not the exact phrase as the training phrases, but Dialogflow can recognize and give the proper responses.

Figure 16
Testing a text response

Step 2.2.5: We can continue to create four other intents to answer four other facts about the solar system. In addition, you can expand this application by adding more intents representing each planet in the solar system to make the SolarSystem study more comprehensive such as Saturn, Mercury, and Venus.

Step 3: Use a Web Demo to test and view the conversation.

As in Figure 17, click “Integrations” on the left-hand sidebar to view the conversation in Web Demo, Dialogflow Messager, or other applications. Then click Web Demo, you will see the prompt window in Figure 18. Next, click the URL link; you will be directed to a web page shown in Figure 19. Now you can start a conversation, shown in Figure 20.
Figure 17

Beginning the web demonstration

Figure 18

Starting a web demo conversation

https://bot.dialogflow.com/e5d5a1e4-ab8a-41fa-9a09-461f9f34a4d51

Add this agent to your website by copying the code below:

```html
<iframe allow="microphone;" width="358" height="438"
src="https://console.dialogflow.com/api-client/demo/embedded/a9b5a1e4-ab8a-41fa-9a09-461f9f34a4d51"
1">
</iframe>
```
**Figure 19**

*Integrating chatbots into your site*

![Image of Dialogflow interface](image1.png)

**Figure 20**

*Sample chatbot discussion*

![Image of chatbot conversation](image2.png)
REFERENCES


APPENDIX

More details on Dialogflow: https://cloud.google.com/dialogflow

Basics of using Dialogflow ES https://cloud.google.com/dialogflow/es/docs/basics

Editions Comparison: https://cloud.google.com/dialogflow/docs/editions#--text=A%20free%20edition%20that%20provides%20suitable%20to%20experiment%20with%20Dialogflow.&text=The%20Dialogflow%20Essentials%20(ES)%20Edition%20is%20the%20standard%20ES%20agent%20type.

Dialogflow ES quick start https://cloud.google.com/dialogflow/es/docs/quick
Generative AI Writing Tools: 
How They Work, What They Do, and Why They Matter

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We offer insights from Bill Green’s *Literacy in 3D* model in order to support teachers integrating generative artificial intelligence writing tools (GAIWTs) like ChatGPT into their classrooms. This model supports teachers by designing pedagogy relating to three key overlapping domains of 1) operational, 2) cultural and 3) critical literacies. We introduce the model and describe its implications for teachers who are creating learning experiences with GAIWTs, concluding that best practice in AI-related writing education needs to cautiously embrace GAIWTs by attending to all three of the model’s domains. We provide some examples of writing tasks that involve the use of GAIWTs to demonstrate how the three dimensions operate. Ultimately, we aim to inspire teachers to think about both the potential benefits and the problems that may result from students participating in a world where text is increasingly generated by AI tools.

INTRODUCTION

In November 2022, *ChatGPT* was released by OpenAI and changed the conversation about how and why writing is taught. This conversation, at first, focused on high school and college writing courses. However, the tone quickly shifted as districts like New York and Los Angeles in the United States, and the states of Victoria, New South Wales, Tasmania and Queensland in Australia, moved to block the site from school networks. As 2023 dawned, and artificial intelligence (AI) tools continued to enter the market at an exponential rate, educators could hardly open an email newsletter, scan social media, or participate in a professional development session without being challenged to think about the pros and cons of the impending AI revolution.

As educators, individually and collectively, our work to understand the implications of—and engage in the use of—Generative Artificial Intelligence Writing Tools (GAIWTs) such as *ChatGPT* raises many warranted concerns. These include questions about the ethics of using GAIWTs to plan lessons and provide feedback on students’ writing; it also includes concerns about students using such tools to avoid the writing process and lose out on the critical and creative thinking that undergirds that process. As we—two university-based teacher educators, one situated in Australia and one in the United States—also wrestle with these questions, we want to first define what GAIWTs are, review recent research, and then consider practical implications for PK–12 educators, especially those in grades 4–12.

GAIWTs are based on large language models (LLMs), or neural networks, which can predict sequences of words by “reading” huge bodies of text. These tools have been producing human-quality text for some years now, since the release of earlier models of *ChatGPT*. However, with the 2022 release of *ChatGPT*, a large language model was married with a conversational chatbot, and the world woke to new possibilities. More than just producing text, *ChatGPT* could refine that text based on additional interactions with the user. As one of an emerging wave of AI writing tools that will be integrated with Google’s *Bard* and Microsoft’s *Bing*, as well as separate tools such as *Sudowrite*, *Rytr*, and *Jasper*, *ChatGPT* merits the attention of K–12 educators, both for their own use as well as in thinking about how such tools can be useful for students.

GAIWTs are being embedded in word processors, email clients, and other composing spaces. They will soon become as ubiquitous as spelling and grammar checkers in most education and workplace settings. AI is already being
integrated into learning management systems and word processors in the form of writing coaches and other supports. As with all newer technologies, it requires educators to consider how to respond to GAIWTs in creative and critical ways.

RESEARCH REVIEW

Humans have been writing with and across various technologies for millennia, from cuneiform tablets to papyrus to pixels (Baron, 2001). Even in our lifetimes, people have learned how to write—and taught students how to write—with pencils, pens, and typewriters, as well as keyboards, personal computers, laptops, iPads and smartphones. These writing tools and technologies are shaping our communications and our writerly identities.

In 2010’s Because Digital Writing Matters, the authors describe digital writing as “compositions created with, and oftentimes for reading or viewing on, a computer or other device connected to the Internet” (National Writing Project, et al., p. 7, emphasis in original). Jumping forward to 2019, the National Council of Teachers of English in the United States articulated a “Definition of Literacy in a Digital Age” that anticipated ongoing change, describing literacies that were “interconnected, dynamic and malleable” (para. 2). Without a doubt, GAIWTs will play a role in digital writing, and as part of students’ broader digital literacy.

Given this, Bill Green’s (Green, 2012) Literacy in 3D model provides ways to explore these practices in a time of exponential AI-related change. This model—which describes three dimensions of literacy education: operational, cultural and critical—emerged from New Literacy Studies, and has been adopted and endorsed by key figures in digital literacy (see Beavis & Green, 2012). It supports teachers to move beyond technicist notions of literacy, which are based only on skills, and acknowledge the complexity of learning to communicate. Moreover, the model is also pedagogical, in that it can be a resource for teachers in designing learning sequences and lessons. It is a reminder that the future lives of students will require “using written language for thinking and meaning” (Green, 2012, p. 4), not only for compliance-based activities such as following grammar rules or spelling correctly.

In the implications below, we contemplate the proficiencies educators and students need to develop with GAIWTs, through the dimensions of the 3D model, providing practical suggestions. These propositions are not exhaustive, but illustrative of the synergistic, overlapping dimensions of the model. This brief explanation of each dimension shows how it can inform current conversations about AI:

● “Operational” refers to language competencies and the technical “how to” of literacy (e.g., how to write a clear and instructive prompt for a GAIWT).
● “Cultural” connects to content and meaning making in diverse contexts (e.g., how authors, artists and poets are using GAIWTs to enhance the impact of their work).
● “Critical” foregrounds the power struggles related to meaning-making systems (e.g., understanding who has access to GAIWTs, and how much that access will cost in economic, social, and environmental terms).

While educators tend to focus on the operational and cultural aspects, this is never enough (Bacalja et al., 2022). Even in these early days of GAIWTs, others have recently renewed a call for a critical orientation to digital literacies (Bacalja et al., 2021) including specifically in relation to AI writers (McKnight, 2021; Robinson, 2023). The questions of both why and how to engage with GAIWTs, thus, resonate with our historical interest in and continued advocacy for the use of digital writing tools.

IMPLICATIONS

It is challenging to predict exactly how GAIWTs will be integrated with digital tools common in the K–12 classroom including office suites from Google and Microsoft, as well as learning management systems and other specific educational technology applications. However, Green’s 3D model can be used to outline specific ideas that K–12 educators, especially those in the upper elementary to high school grade levels, might use to integrate and study GAIWTs.

First, in the Operational Dimension, educators can think about how to use language effectively to operate effectively in specific contexts, such as how to talk about and use GAIWTs with their students. For instance, this may mean:
• knowing how to engineer an effective prompt to “prime” the GAIWT; being able to push a GAIWT’s chatbot to improve outputs, though “conversation”.
• knowing the difference between various tools, and how to maximize GAIWTs for rhetorical effects like tone, sentence length, and humor.
• possessing the syntactical and grammatical fluency to edit AI-produced text; being able to synthesize content from various multimodal content generators.
• transposing across different software and how to document human and/or AI input using referencing and citation protocols.

In practical terms, we might consider how elements of the operational dimension could be modeled during a lesson with students. Imagine that an upper elementary teacher is working to help her students understand the elements of an effective op-ed essay and the appropriate use of evidence to support an argument. With a tool like ChatGPT or Bard, she could ask the GAIWT to describe the characteristics of an effective op-ed, copy/paste an existing op-ed and ask the GAIWT to analyze its evidence for rhetorical effectiveness, and then show students how to generate topics for their own op-ed. In doing so, she would also be sure to “track changes” in her word processing document to show text generated by the AI as compared to her own, and add an appropriate citation in MLA, APA, or other format (University of Queensland Library, 2023).

Second, in the Cultural Dimension, educators can move deeper into conversations with students to socialize them into a culture of AI-writing. In this sense, students need to become both socially and technically proficient in the use of GAIWTs, deploying them in sophisticated and beneficial ways. For instance, this could include exploration of how:

• GAIWTs are used in various industries (such as journalism, publishing, the arts, the sciences, and more), and how these uses are connected to what students need to learn at school.
• GAIWTs might be used for collaboration and co-authorship; how they might be used to enhance interpersonal communication; how they might be used for specific writing skills and in stages of the writing process, such as brainstorming, planning and drafting.
• GAIWTs can be employed appropriately for particular tasks and audiences, such as about pages in blogs or to deepen research skills and understanding of topics through dialogue with chatbots.

For this example, imagine a middle school language arts class where a teacher is helping students create an interdisciplinary essay to synthesize data from an experiment on water quality in their life sciences course. Because their essays are getting lengthy and knowing that their writing must be clear and concise for a scientific audience, the teacher asks them to take their entire essay and have a GAIWT summarize what they have already written at 25%, 50%, and 75% of the current word count.

Then, she invites students to compare the outputs of these condensed texts, examining what clarity was gained in the synthesized versions, yet also to consider what additional information might have been lost. She also encourages students to use the GAIWTs to rephrase key definitions of scientific concepts, comparing their own initial paraphrases from the textbook definitions to the GAIWT alternatives and, if they chose to use any AI generated text, to cite it appropriately.

Third, from the Critical Dimension, students need to begin thinking about power, analyzing and mapping power relations, resisting assumptions of neutrality, and challenging dominant meanings. This would include:

• exploring the media “hype” around GAIWTs, to recognize their limitations (Selwyn, 2022).
• recognizing linguistic biases inherent in the bodies of writing used to train AI writers as well as the parameters, ownership, and quality of this material.
• naming threats to society and academic norms, including to notions of truth, privacy, academic integrity, intellectual property, copyright, plagiarism, and cheating.

For this final example, we can picture a high school advanced composition course, where students have been exploring the rhetorical approaches used by civil rights activists throughout American history. They have been working with GAIWTs to explore some key elements of their speeches, as well as spirituals and recent hip hop lyrics. In doing so, students have been trying several tasks, including having the GAIWTs write about how historical figures such as Martin Luther King Jr. would have responded to the #BlackLivesMatter movement and recent songs released by artists like Kendrick Lamar and Beyoncé.
In doing so, they discover that the GAIWT is providing historically inaccurate information and also produces a few phrases that are overtly racist. This spurs a conversation about the possible training corpuses (bodies of data) from which this particular GAIWT is generating new text, and how racist ideas in pre-existing text can permeate the output. They continue to discuss whether an AI-generated response from a historical figure like MLK is appropriate and useful to use in their own work, as well as how to cite it.

Through these three examples of GAIWTs in action—elementary writers exploring op-ed writing, middle school students writing in a new discipline and genre, and high school writers examining issues of linguistic discrimination evident in LLMs—we can see a wide variety of possibilities for PK–12 educators, especially upper elementary/primary to high school educators. With Green’s 3D model in mind and bringing an intentional focus to the operational, cultural, and critical dimensions of literacy, we can work to move beyond our initial apprehension of AI tools into more productive pedagogies. There is more to learn, of course (see the Appendix for sources for further reading).

Yet, we contend that by incorporating the Literacy in 3D model in the design of learning experiences, teachers can support students “not simply to participate in the culture but also, in various ways, to transform and actively produce it” (Green, 2012, p. 7). This is surely the aim of a holistic and authentic writing education and will continue to be so as we—and our students—learn to write with GAIWTs.

REFERENCES


APPENDIX

Five Recent Resources for Educators Related to Generative AI Writers

1. OpenAI’s Educator Considerations

This is an overview for educators created by teachers, for teachers, and published by the company that created ChatGPT. Definitely something to read before you begin, or continue to use this service, if you have not read it already. [https://platform.openai.com/docs/chatgpt-education/educator-considerations-for-chatgpt](https://platform.openai.com/docs/chatgpt-education/educator-considerations-for-chatgpt)

2. How to cite and reference GAIWTs

There has been much controversy about how to cite and reference GAIWTs. Of course, you can always ask these tools themselves how to reference them and they will give you a nicely formatted reference, based on detailed instructions in your prompt. Or you can use a guide like this one from The University of Queensland’s Library. [https://guides.library.uq.edu.au/referencing/chatgpt-and-generative-ai-tools](https://guides.library.uq.edu.au/referencing/chatgpt-and-generative-ai-tools)

3. Ideas for working with and around GAIWTs

Here is a set of ideas to support teachers either incorporating GAIWTs into the classroom or setting tasks that preclude using them. We suggest teachers in professional learning sessions discuss these suggestions, make links to the operational, cultural and critical domains, and ultimately evaluate them. For example, treating class discussion as a text to refer to in writing sounds ChatGPT-proof… until you remember AI tools on phones can record and transcribe class discussion, and then it can be inputted as a source for ChatGPT to draw on in writing an essay. [https://www.edutopia.org/article/chatgpt-student-writing-middle-high-school/](https://www.edutopia.org/article/chatgpt-student-writing-middle-high-school/)

4. Asking Technoskeptical Questions about ChatGPT

In this April 2023 blog post on the Civics of Technology site, Daniel G. Krutka & Marie K. Heath apply their “five technoskeptical questions” specifically about ChatGPT, with the intent of pushing the conversation further than one of academic honesty and into the possible negative outcomes for students and educators when using such tools. [https://www.civicsoftechnology.org/blog/asking-technoskeptical-questions-about-chatgtp](https://www.civicsoftechnology.org/blog/asking-technoskeptical-questions-about-chatgtp)

5. ChatGPT & Education

Made available by Torrey Trust as an open e-book, ChatGPT & Education covers both what ChatGPT can and cannot do and offers a summary of key points related to privacy, trustworthiness, assessment, source citation, academic labor, and plagiarism. She provides educators with an ever-updated list of resources in the Creative Commons-licensed book. [https://bit.ly/3M5tE57 OR https://docs.google.com/presentation/d/1Vs9w4f8Px-rizDWyaYoB-pQ3DzK1n325OgDgXsnt0X0/edit#slide=id.p](https://bit.ly/3M5tE57 OR https://docs.google.com/presentation/d/1Vs9w4f8Px-rizDWyaYoB-pQ3DzK1n325OgDgXsnt0X0/edit#slide=id.p)
Generative AI Technology to Support High School Students Experiencing Challenges With Writing

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Writing is an important aspect of language development that some students find challenging to master. Schools and teachers play an important role in supporting students’ writing progression. Part of this role includes the facilitation of, and access to, resources that can support students who are experiencing challenges in producing written text. This chapter examines the ways in which artificial intelligence (AI) tools can support high school students’ writing and, more specifically, students who are performing below their grade level. New AI writing tools can alter both how students write and what they need to learn to become capable writers. The tools are becoming more sophisticated and are beginning to have an impact in schools. The AI tools featured in this chapter include editing tools and text generators. Throughout the chapter, examples are provided to demonstrate how the tools can be incorporated into high school lessons. Some limitations of AI tools to support writing are outlined, including ethical issues. Specific considerations for teachers seeking to incorporate AI technologies are presented. An appendix includes links to further information related to school policies, ethics, and AI in education discussion groups.

INTRODUCTION

Writing challenges impact approximately 15% of the school-age population and children who fail to develop age-appropriate writing skills are at a significant disadvantage (Dockrell et al., 2019). Students experience challenges in producing written text for a variety of reasons. This includes diagnosed conditions such as dysgraphia and expressive language disorders, through to gaps in learning due to high absenteeism or poor instruction in the early years (Westwood, 2008). Regardless of the underlying cause, the challenge for high school teachers is to ensure these students can actively participate in lessons alongside their peers and are provided with feedback and strategies that will empower them to continue to improve and build their writing skills.

The release of ChatGPT in late 2022 has brought about lively debate on the use of AI in education settings. In this chapter, we explore the ways in which generative AI tools support differentiation and personalised learning for students experiencing challenges with text production. We critique the technologies for their potential to support writing and conclude by identifying pertinent considerations for educators seeking to incorporate the affordances of AI tools to support high school students who are experiencing difficulty with writing tasks.

RESEARCH REVIEW

There is a long history of assistive technologies being used to support people with special education needs. Hand-held lenses were used for people with visual impairment as far back as 1000 A.D. (Robitaille, 2010). In more recent history, since the early 1980s, students with disabilities have benefited from computer-assisted instruction (CAI) and word processing features (such as spell check and word prediction), alongside multimedia technologies (Jeffs et al., 2008). The integration of online assistive tools has evolved, with many technological supports now seamlessly embedded through mobile devices (Maher & Young, 2017; Wu et al., 2020). In the mid-2020s we are currently experiencing a period of technological advancement in the form of AI tools that have the potential to assist students with disabilities and learning difficulties in new ways.
One emerging form of AI is tools that support the generation of text. According to Tate et al. (2023), AI tools like ChatGPT can support students with language or learning disabilities who struggle with writing. These tools may also encourage experimentation and increase student motivation (Kangasharju et al., 2022). New speech recognition technologies are becoming common in homes and educational settings and will become a central part of future life (Shakhovska et al., 2019). In addition, AI text editing tools (such as grammar checkers) can also support students to engage in critical reflection during the writing process (Toncic, 2020). Whilst the potential of these tools to support learning is only now emerging through empirical research, it is suggested that AI applications will provide an assistive role, rather than replacing teacher instruction (Murphy, 2019).

One way to understand the application of AI technology to support student writing is through the lens of Universal Design for Learning (UDL). While originally developed as a way of “providing access to the curriculum for students with disabilities, [UDL] has simultaneous benefits to many other students. UDL provides a vision for breaking the “one-size-fits-all” mould and therefore expands the opportunities for learning for all students with learning differences” (Edyburn, 2005, pp. 17–18). UDL incorporates multiple or flexible representations of information and concepts (the “what” of learning); multiple or flexible options in expression and performance (the “how” of learning); and, multiple or flexible ways to engage learners in the curriculum (the “why” of learning; CAST, 2023; Meo, 2008). Recognizing and responding to diversity is a core motivation for engaging in UDL practice and generative AI tools support multiple means of representation, expression and engagement through the extensive and varied levels of accommodation and adjustment these tools enable (Banes & Behnke, 2019).

**IMPLICATIONS**

The implications section is divided into two parts. The first section focuses on the practical use of AI writing tools to support students who are experiencing challenges with the writing process and editing. The second section is focused on the associated ethical implications and presents a list of considerations for educators when evaluating the value of AI technologies as assistive tools for students requiring additional writing support.

**AI writing tools**

AI technologies can provide personalised learning to assist students with SEN to engage in inclusive writing experiences that align with their peers’ activities. The tools can help students develop writing skills at their own pace and in ways that work best for their individual abilities. A powerful feature of these tools is that they provide students with immediate feedback and error correction when the teacher is not directly available. Drawing on the affordances of these tools, two types of AI are examined: editing tools and text generators.

The tools used as illustrative examples in this chapter can be accessed as either a free or paid versions. The cost of the paid versions varies depending on how they are accessed and the types of features that are selected. Additionally, the cost may vary in different countries.

**Editing tools**

For students with the capacity to create texts independently, but not at grade level, several AI-powered tools provide editing assistance and can be embedded into software that students are already familiar with, such as Word, email, and social media platforms. This is useful as students are not required to learn new programs. Such tools can be exploited to explicitly demonstrate to students how their writing could be improved.

Grammarly is one such tool. Grammarly not only corrects spelling and grammar but will rephrase sentences and alert students to the tone of their writing. The use of colour-coding draws student attention to the words in the text that are being corrected, as depicted in Figure 1.

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While all students could benefit from utilising a tool such as Grammarly, students requiring greater teacher instruction to master editing skills would particularly benefit. For example, in a high school English class where students are required to submit a narrative text, Grammarly could be used to support the student/s who have not developed adequate proofreading skills. Rather than waiting to receive teacher feedback at a later stage, the student/s could use Grammarly, or a similar tool, during the final revision process before handing in for marking. In final reporting, the teacher would acknowledge the accommodation that was made; noting that the narrative product was supported using Grammarly.

Quillbot is another tool that can be embedded into existing software and can rephrase text according to the author’s desired tone. A benefit of this tool is having the original and revised text side-by-side, which enables students to easily compare the versions (Figure 2). This tool goes further in that it can expand or shorten the text and, in doing so, is beneficial to students who are learning how to build on their ideas or are learning how to summarise. Again, in highlighting the changes to students a form of 1:1 instruction is provided at times the teacher is not available for individual instruction.
Quillbot could be used during the writing process. An example of this is a year 10 history class where students are writing an information report. For students in this class who find such a task challenging, Quillbot can provide just-in-time support by rephrasing student-produced text into more formal language or suggesting synonyms to broaden the student’s vocabulary.

Other AI tools with similar features are WordTune and copy.ai. Teachers need to consider which tools can be seamlessly embedded into a platform a student already uses and whether a subscription is required to access all features of the tool. To be effective as instructional aids, teachers must build in a period of instruction when introducing an AI tool. During this period of instruction, the teacher will need to explicitly teach students how to use the feedback features to avoid students automatically accepting changes without consideration.

**Text Generators**

AI editing tools such as Grammarly, Quillbot and WordTune are useful to support students who have the capacity to write independently but struggle with spelling, grammar, and syntax. For students experiencing challenges in formulating ideas and collating new information, AI text generators may provide the support required to participate in classroom-based writing activities alongside their peers. Recently, much discussion has focused on ChatGPT. This tool enables a student to artificially generate text based on their own prompt and this text can be used as the basis for a writing task that enables the student’s inclusion in a lesson. Similar tools exist, that overcome some of the current limitations of ChatGPT.

One such tool is Jenni.ai. This tool builds text based on the user’s prompt but creates the text sentence-by-sentence, thereby requiring the student to read and consider each sentence before proceeding. This sentence-by-sentence approach also allows students to adjust the direction of the text relevant to their desired writing goal. During the writing process additional instructions can be provided, such as writing in more depth, or writing an opposing argument (Figure 3). These features position the tool as substantially more useful for instructional purposes, as compared to AI tools that automatically construct an entire text.

**Figure 3**

Sample of writing tools available through Jenni.ai

Tools such as Jenni.ai are particularly useful instructional tools for teachers wishing to focus on a specific aspect of text construction. For example, in a Year 8 English class, where students are writing persuasive texts or preparing for a debate, a student who has not mastered the necessary skills can use the Jenni.ai (or similar) to assist them to formulate
an opposing argument. These tools can be used to explicitly support specific parts of the writing process that a student is struggling with, for example, writing an introduction or writing a conclusion.

Jenni.ai (and others like it) allow the user to request references (Figure 4), which is valuable for high school students learning referencing techniques. This overcomes issues surrounding the first generation of ChatGPT which produced false references. References may also be formatted into the desired form, such as Harvard or APA.

**Figure 4**

*Example of referencing using Jenni.ai*

![Example of referencing using Jenni.ai](image)

Perplexity.ai, is another tool that creates text in response to the user’s prompt. It includes the references that were used to create the text and provides prompts that suggest follow-up investigations (Figure 5).

Perplexity, and similar tools, are useful to high school teachers who set assignments that require students to include reference sources. Such tools could be used by students at the outset of the writing process to help them gather appropriate resources to support their writing. Perplexity is particularly useful to students who struggle to develop a comprehensive response to assignment questions as these students can use the ‘related’ section, as shown at the bottom of Figure 5 to continue to generate new ideas for writing.

As with ChatGPT and Jenni.ai, we are not suggesting that students simply use Perplexity to create text. We argue that these AI tools can be used to enable a student to independently engage in classroom activities alongside their peers, where they would otherwise be unable to do so. Also, the specific features of the tools should be used to support learning, only after the student has received instruction from the teacher on appropriate use of the tools.
Ethical implications

The use of AI in education raises important ethical considerations that must be rigorously debated (e.g. who owns the data, privacy, broadening the digital divide). There is also concern about student learning as Tate et al. caution, “[T]eachers will have to balance the teaching of effective writing with AI and writing without AI to ensure that students build up the necessary ‘muscle tone’ (p. 10). The use of AI technology, like any technology, should be used to support the writing process, rather than replace it. Schools need to establish guidelines that define what level of AI assistance is appropriate for students to receive from AI tools in relation to classwork, homework/assignments, and assessment tasks.

At the time of writing, Open AI terms and conditions state that users “must be at least 13 years old to use the Services. If you are under 18, you must have your parent or legal guardian’s permission to use the Services” (OpenAI, 2023). This limits the use of apps like ChatGPT to middle school or high school students, and to students where parental permission has been obtained. Other apps may have different restrictions, so it is important to investigate these before incorporating the tools into classroom practice.

Considerations

Before introducing AI technology to assist a student or group of students experiencing writing challenges, there are several considerations that must be deliberated:
1. Terms of use. Are there age restrictions? Is parental consent required?
2. Does the technology integrate with any other assistive devices the student has already mastered or requires? For example, voice recognition software.
3. Can the AI tool be used across a number of subjects/classrooms?
4. Does your school offer professional development opportunities to enable teachers to explore and understand how to use the technology?
5. Does the student have the capacity to be taught how to use the tool effectively? How long would it take to teach the student how to use the technology?
6. Who will be responsible for instructing the student on how to responsibly use the technology? When and where will this instruction take place?
7. Is the use of the tool a short-term measure or will the student require support long-term? If short-term, what strategies will be in place to transition the student to a less intrusive support?
8. Will the student have access to the technology in their homes? Is there a parent or caregiver that can support the student in the home?

Finally, it is recommended that the teaching team, including any specialist educators, brainstorm potential unintended, negative consequences. For example, lack of engagement with the writing process, over-reliance on AI, loss of creativity, or misunderstanding of concepts. A teacher then needs to weigh up the cost-benefit of introducing the technology to support inclusion over the potential negative consequences.

REFERENCES


APPENDIX A

AI tool descriptors

Grammarly [https://www.grammarly.com/]
The basic (free) Grammarly version is an online typing assistant that suggests corrections for numerous aspects of writing such as spelling, grammar and punctuation within Gmail, Facebook, Google Docs, LinkedIn, text messages, and many more services and applications. Grammarly Premium (paid) includes tools to help improve word choice and tone of writing and also a plagiarism checker. GrammarlyGO (paid) is an AI co-creator to compose, ideate, rewire, and reply, informed by your context and goals.

Quillbot [https://quillbot.com/]
Quillbot is described as a paraphrasing tool. Its free features include the grammar checker, synonym options, and rephrasing tool. It rewrites text based on selected writing modes: standard, fluency, formal, simple, and creative, as relevant to the writer’s intended audience. The basic (free) Quillbot tool can also shorten or expand on text. The paid premium version increases limits (e.g. from 1200 words to 6000 words in summariser) and includes additional features such as plagiarism checker, tone detector and paraphraser history.

Jenni.ai [https://app.jenni.ai/]
The tools available using Jenni.ai include:
- Autocomplete (co-construction writing tool)
- Customized styles (choose the tone and type for personalized AI generation)
- In-text citations (Jenni consults the latest research and cites in APA, MLA or Harvard style)
- Paraphrase & Rewrite (paraphrase any text in any tone. Rewrite the internet customized to you)

WordTune [https://www.wordtune.com]
WordTune is an AI writing assistant that identifies writing errors, suggests alternative tones, and generates sentences to expand on what you’re writing. WordTune Read will instantly highlight the most relevant information and add short summaries to be displayed next to each passage. Besides reading, summaries can easily be exported or copied to use outside the app.

Copy.ai [https://www.copy.ai]
Copy.ai is a writing tool that generates high-quality essays and academic papers. To save time, it provides rich text editing, ideas, and flexibility. Copy.ai provides support for creating quality content. There are a variety of output options and a variety of templates to choose from.

Perplexity.ai [https://www.perplexity.ai]
Perplexity AI is a chatbot that uses machine learning and Natural Language Processing (NLP) to respond to user’s questions and prompts and also includes links to citations and related topics. Perplexity uses current information, including footnotes with links to the sources of the data.
APPENDIX B

Links to further information

Artificial Intelligence (AI) in Education

Artificial Intelligence in Education

ChatGPT, Chatbots and Artificial Intelligence in Education
https://ditchthattextbook.com/ai/

Future of Testing in Education: Artificial Intelligence
https://www.americanprogress.org/article/future-testing-education-artificial-intelligence/

How Is AI Used In Education — Real World Examples Of Today And A Peek Into The Future

School policy

Artificial Intelligence Policy in Secondary Schools

School Policies for Integrating AI in Classroom Practices

Setting school policy about AI: A cautionary tale
https://ditchthattextbook.com/ai-conversations/

ChatGPT: Education assessment, equity and policy

Ensuring a measured response to ChatGPT

Ethical considerations

Exploring the ethics of artificial intelligence in K–12 education

Ethical principles for artificial intelligence in K–12 education
https://www.sciencedirect.com/science/article/pii/S2666920X23000103

How Should We Approach the Ethical Considerations of AI in K–12 Education?

Ethical Considerations When Using Artificial Intelligence-Based Assistive Technologies in Education
A Year in K–12 AI Education

AI in education discussion groups

LinkedIn
AI for Quality Education and Research
https://www.linkedin.com/groups/13949843/

Facebook
AI and education: https://www.facebook.com/groups/53053990630012/
ChatGPT in Education: https://www.facebook.com/groups/744858756989529

Twitter
AI group: Centre for Education and Training
https://twitter.com/AiGroup_CET
Embracing ChatGPT in Foreign Language Writing Classes: Potentials and Challenges

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The popularity of artificial intelligence (AI) writing tools, particularly ChatGPT, has been rapidly increasing in recent months. ChatGPT is a language program with capabilities beyond smart writing, such as doing research, analysis and writing. With regards to generating written text, it is possible for tools like ChatGPT to perform many tasks in our daily lives, which has led some educators to be concerned about the increase in cheating and the possibility of assignments being completed by AI applications, leading to the end of writing classes. Some schools even consider it necessary to ban such tools. However, it must be remembered that as with every new technological development, ChatGPT also has the potential to complement, enhance, and enrich students’ learning experiences if used wisely and creatively. Although some students may possess technological skills, it does not necessarily mean they know how to utilize ChatGPT for academic purposes. The popularity of ChatGPT also offers teachers the opportunity to introduce their students to these resources and engage in meaningful discussions about the potentials, limitations, and ethical dimensions of the latest technological tools in educational environments. This study will contribute to a deeper understanding of the role of artificial intelligence in language teaching and how it can be leveraged to enhance the learning experience for students, particularly in writing classes. If we want to see the transformative nature of technological advancements like ChatGPT, educators should not ban them, but rather embrace the opportunities they provide and find ways to incorporate them into lessons.

Keywords: artificial intelligence, ChatGPT, English, K–12 schools, language teaching, L2 writing

INTRODUCTION

The field of education has seen a significant shift in recent years with the advent of new technologies and their integration into the learning process. Artificial intelligence (AI) and natural language processing, in particular, have emerged as valuable tools for enhancing the effectiveness of education (Dong et al, 2022; Hsu et al., 2021; Sumakul et al., 2022). AI technologies such as Scholarcy (https://www.scholarcy.com), Humata (https://www.humata.ai), Canva Magic Write (https://www.canva.com/magic-write), Notion (https://www.notion.so/signup), Cliovis (https://cliovis.com), SciSpace (https://typeset.io) and so on offer new teaching and learning opportunities for educators and students through coaching, content development, and feedback (Godwin-Jones, 2022; Nazari et al., 2021). Recently, one of the most promising tools in this regard is ChatGPT (https://openai.com), a language model developed by OpenAI.

Trained on a vast corpus of diverse text data, ChatGPT is capable of generating highly coherent and relevant responses to a wide range of questions and topics (Deng & Lin, 2022). This has made it an attractive tool for education as it can help students receive instant feedback on their work and improve their understanding of subject matter. Thus, AI technology can overcome some of the limitations of traditional classroom settings, such as short class periods, difficulty in providing feedback to every student, and little exposure to the target language.

To make a modest contribution to the growing research on AI in education, this study aims to examine the potentials of ChatGPT in promoting self-directed learning and autonomy in language classes, and to provide recommendations for its effective use in foreign language writing classes.
RESEARCH REVIEW

Numerous studies have highlighted the virtues of AI in language learning as it brings the promise of personalized learning. AI systems have been found to process students’ language input, give feedback to their grammar, use of vocabulary or text organization in a sophisticated manner (Bailin, 1987; Holland et al., 1993). Some studies have focused on AI based writing assistant’s effect on students’ learning (Gayed et al., 2022), and how AI based automated feedback influenced students’ writing accuracy (Han & Sarı, 2022). Automated written corrective feedback tools have been examined in English as a foreign language (EFL) settings in terms of their effectiveness in providing feedback to the students’ writing (Dizon & Gayed, 2021; O’Neill & Russell, 2020). Those studies in the reviewed literature have revealed that AI technologies such as automated feedback have positively impacted students’ learning experience. One of the benefits is that it promotes learner autonomy. For instance, the prompt and sufficient feedback from AI systems allows students to independently revise their drafts in private, leading to an increased level of independence. Additionally, the feedback enhances the accuracy of students’ writing, which is crucial in their academic pursuits. Moreover, AI technologies facilitate students’ learning and internalization of writing skills, such as the use of passive voice to mitigate the power of the argument, so AI based programs have been shown to affect the quality of student writing positively (Grimes & Warschauer, 2010; Nunes et al., 2021). Another area of investigation related to AI programs has been machine translation. Some studies have investigated GoogleTranslate’s impact on students’ writing (Chang et al., 2022) and surveyed students’ opinions about using it and yielded positive outcomes (Fredholm, 2015; Vinall & Hellmich, 2021). Those studies have shown that the use of machine translation as a tool for learning promotes positive attitudes towards anxiety, motivational beliefs, and task complexity. Therefore, it can be concluded that AI technologies play a significant role in enhancing the quality of education by promoting learner autonomy, improving accuracy, and enhancing positive attitudes towards learning.

As a newly developed AI tool, the integration of ChatGPT into language teaching is suggested to offer numerous advantages; however, the number of studies exploring its use in language classes is scarce. Thus, this study aims at exploring the applicability of ChatGPT to language teaching, and it will focus on the implications and possible challenges of using ChatGPT in EFL writing classes with relevant examples.

IMPLICATIONS OF CHATGPT FOR LANGUAGE TEACHING AND WRITING CLASSES

Opportunities for language teachers

ChatGPT can support language teachers in using their time efficiently as it can help them on various issues such as providing feedback, preparing language exercises for students and assisting them in planning their lessons.

Providing personalized feedback

In the process of learning, feedback enables students to reconsider their previous work actively and discover new ways to improve it (Jensen et al., 2021). However, teachers need to spend a lot of time and effort in order to provide immediate and insightful feedback to the students, particularly when they are faced with large class sizes (Gao & Ma, 2022; Nazari et al., 2021). In order to help teachers not only provide immediate feedback to the students but also save time, the integration of ChatGPT into language teaching has shown to bring about numerous advantages. Teachers can submit students’ written work to ChatGPT so that it can provide suggestions for improving grammar, syntax, and coherence. In Figure 1, ChatGPT’s feedback to an opinion paragraph written by an A2 level student is given:
Figure 1

Giving personalized feedback

Please act as an English teacher and give feedback to the following opinion paragraph on the topic “Daily homework is necessary for students” written by an A2 level learner of English. Please add your suggestions what the student can do to improve the area that s/he lacks competence in. “On the whole, I agree with you. Daily homework is necessary for students because daily homework is infinite so teachers can give about matter a lot of homework. I feel like, this is amazing. So much so that students choose these subjects because self-learning is always more catchy but to my mind, these homework shouldn’t always be. If these always be, students not to take seriously in this way, these don’t make import. There is so information and science in this world. We contact with people in order to learn. First of all with our teachers. Daily homework is also instructive. Homework is the be all and end all for college students. I think, we have to grasp this point. People can already find a lot of knowledge from books. The important thing is what information necessary for us. That’s the whole point and this one tell us our teachers. Whence, daily homework is a great vehicle for us.”

Overall, the paragraph makes a good attempt at expressing an opinion on the topic of daily homework. However, there are several areas where the student could improve their writing to make their point more clearly and effectively.

Firstly, the student needs to work on sentence structure and grammar. There are several instances where the sentence structure is unclear or incorrect, which makes it difficult to understand the point being made. Additionally, there are several grammatical errors that need to be addressed to make the writing more fluent and professional.

Secondly, the student needs to focus on clarity of expression. There are several instances where the point being made is not clear, and the writing is difficult to understand. For example, the sentence “If these always be, students not to take seriously in this way, these don’t make import” is confusing and unclear.

Thirdly, the student needs to work on vocabulary and word choice. There are several instances where the wrong word is used or the vocabulary is too simple for the intended meaning. For example, the phrase “homework is the be all and end all for college students” could be improved by using a more precise or sophisticated vocabulary.

To improve their writing, the student should focus on improving their grammar, sentence structure, and vocabulary. They can do this by practicing writing regularly, reading more, and using online resources to improve their writing skills. Additionally, the student should work on clarifying their ideas and expressing themselves clearly and concisely. Finally, they can seek feedback and guidance from their teacher to help them improve their writing skills.

In the Figure 1, the student’s written work is submitted to ChatGPT and it is asked to act like a language teacher and give feedback to that opinion paragraph written by the student. ChatGPT goes over the text and it highlights its strengths and weaknesses by giving examples from the student’s text. This can help teachers recognize the areas where students have difficulty and assess students’ improvement accurately. Such support can save language teachers a lot of time and effort for the tasks which require personalized feedback (Kasnceti et al., 2023).
Preparing personalized language exercises

In contrast to conventional one-size-fits-all learning approaches, personalized learning practices allow instructors to customize lessons and deliver them to specific learners (Al-Badia et al., 2021). In this regard, another advantage of using ChatGPT in language teaching is its capacity to generate personalized language exercises. For example, considering each student’s individual language abilities and needs, language teachers can use ChatGPT in an assistive way to prepare personalized language exercises such as gap-filling exercises, sentence-completion exercises, or writing prompts, which are tailored to the student’s language level. Thus, ChatGPT can contribute to the enhancement of language skills and creativity in addition to saving time and effort for language teachers. In Figure 2, ChatGPT is asked to produce a personal practice for the student who wrote the essay in the Figure 1:

Figure 2
Preparing personalized exercises

In the example provided in the Figure 2, ChatGPT is asked to prepare a gap-filling exercise for the student who wrote the essay in Figure 1. In a few seconds, it produces eight gap-filling items on conjunctions as requested by the teacher. Such assistance can contribute to the production of personalized materials for the students and also can save a lot of time and effort for language teachers.

Assisting teachers in planning their lessons

Teachers can save time and concentrate on other duties since ChatGPT can enhance instruction, such as writing guidelines for developing more inclusive and accessible learning activities, advice for diversifying the authors on a reading list or syllabus for the class, methods for utilizing digital tools and applications to improve teaching and learning, and illustrations of how to explain a subject to students of various ages (Trust et al., 2023). Moreover, ChatGPT can be used to produce materials such as puzzles, surveys, and riddles to be used during lessons. In addition, ChatGPT may produce flashcards that aid students in learning critical vocabulary, definitions, and concepts. The figures 3 and 4 show how ChatGPT can be applied to aid language teachers in producing materials for their courses and planning their lessons.
In Figure 3, ChatGPT is given the information that students will study on the topic of “genetically modified food” and it is asked to act as an English teacher and prepare a survey which involves questions related to students’ opinions about “genetically modified food”. It is also directed about the question types and number of the questions. In a very short period of time, ChatGPT produces five survey questions on the given topic as it is required to do.

In Figure 4, ChatGPT is asked to prepare some flashcards on a given topic (travelling) and for a certain grade (8th grade). It produces a list of target words related to the given topic and provides their definitions. Thus, teachers can easily use these flashcards in their lessons to introduce the target vocabulary - maybe with some slight changes - instead of allocating a significant amount of time for preparing such a list of words.

Opportunities for language learners

ChatGPT can support language learners in using their time efficiently as it can help them on various issues such as promoting learner autonomy, fostering peer feedback, brainstorming, and having conversations.
In recent years, there has been a growing interest in autonomous learning due to its flexible and personalized nature (Gibbs & Simpson, 2004). The integration of ChatGPT into language teaching has the potential to revolutionize the learning experience for students, as it promotes self-directed learning and enables students to take an active role in their language learning process.

As ChatGPT can provide personalized feedback, students have the opportunity to write a text in target language wherever and whenever they want and get feedback at any time thanks to its accessibility (Huang et al., 2022). As students have the chance to have an idea about their strengths and weaknesses while writing in target language, they can have more autonomy in their learning process (see Figure 1).

Additionally, as ChatGPT can prepare personalized exercises, the students can ask it to prepare exercises about topics on which they want to improve themselves. They can also ask for certain types of exercises such as gap filling, multiple choice or cloze tests. After doing the exercises, the students can ask ChatGPT to give feedback or provide the correct answers for the related exercises. Such a process of getting personalized exercises from ChatGPT can promote self-directed learning and autonomy in language learning (see Figure 2).

**Fostering peer feedback**

The use of ChatGPT for peer review is another valuable aid in language teaching. In this setting, students can provide feedback to their peers on their writing skills. For example, students can write a paragraph in the target language
and swap the papers and then use ChatGPT to provide feedback to their peers (see Figure 1). This can promote critical thinking and evaluation skills, as well as improve language abilities by taking into account the feedback from others. Additionally, ChatGPT can also generate discussion prompts for group work, which can help to develop interpersonal and communication skills. In this regard, ChatGPT can be used to encourage participant collaboration and teamwork (Rudolph et al., 2023).

**Brainstorming**

One of the major challenges of writing in target language is often stated to be the difficulty to find relevant content. The ability for students to learn through trial and experience is one of ChatGPT’s main advantages. ChatGPT is appropriate for real-time applications since it can produce responses quickly (Rudolph et al., 2023). For example, students can brainstorm with ChatGPT before starting to write on a certain topic as shown in Figure 5.

**Figure 5**

*Brainstorming with ChatGPT*

<table>
<thead>
<tr>
<th>☰ How does social media impact our health? Please give me some prompts.</th>
</tr>
</thead>
<tbody>
<tr>
<td>✍️ How does social media impact our health? Please give me some prompts.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>✍️ Sure, here are some prompts on how social media can impact our health:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mental Health: How social media can affect our mental health? Can it cause anxiety, depression, or stress?</td>
</tr>
<tr>
<td>2. Addiction: Can excessive use of social media lead to addiction? How can it impact our daily lives and productivity?</td>
</tr>
<tr>
<td>3. Cyberbullying: How does social media contribute to cyberbullying? What are its potential impacts on the mental health of victims?</td>
</tr>
<tr>
<td>4. Sleep: Can the use of social media before bedtime affect the quality of our sleep?</td>
</tr>
<tr>
<td>5. Self-esteem: Can social media impact our self-esteem? How does it influence our perception of ourselves and others?</td>
</tr>
<tr>
<td>6. Physical Health: Can the excessive use of social media lead to physical health problems, such as eye strain or neck pain?</td>
</tr>
<tr>
<td>7. FOMO: Can social media contribute to the “fear of missing out” and how does it affect our mental health?</td>
</tr>
<tr>
<td>8. Relationships: Can social media affect our personal relationships? How does it influence communication with friends and family?</td>
</tr>
<tr>
<td>9. Social comparison: Can social media lead to social comparison and how does it impact our mental health and well-being?</td>
</tr>
<tr>
<td>10. Privacy: How does social media impact our privacy and security? What are the potential risks and dangers associated with sharing personal information online?</td>
</tr>
</tbody>
</table>

In Figure 5, a student asks ChatGPT to provide some prompts or ideas about a given topic (e.g. health) and it lists a number of prompts about that topic in a few seconds. The students can go over the items provided by the ChatGPT and can handle the given topic from various aspects in their essays. Such brainstorming with ChatGPT can enable students to enrich their written texts with more content and organize their thoughts before starting to write.

**Simulating realistic language conversations**

ChatGPT offers the opportunity to have realistic conversations; therefore it can be used to promote conversations and group discussions as it can provide immediate responses and guidance to learners (Rudolph et al., 2023). Simulating realistic language conversations can help students develop communicative abilities and become familiar with the flow of natural language. An excerpt from a conversation between ChatGPT and a student is given in Figure 6.
In Figure 6, a student suggests ChatGPT to have some conversation on a topic (health). ChatGPT produces a response to this suggestion by asking the student what to talk about in particular. When the student asks a more specific question related to the topic, it gives an answer, and the conversation goes on. As it is seen in this example, having a conversation with ChatGPT can enable students to see how a conversation may flow in the target language and promote learners’ motivation to be involved in conversations in the target language in real life.

**CHALLENGES OF CHATGPT IN LANGUAGE TEACHING**

While artificial intelligence (AI) tools can be beneficial in language instruction, there is some disagreement among researchers and educators about their use. One of the main concerns is the difficulty in engaging students with AI systems. The impersonal nature of AI and lack of human interaction can lead to a lack of motivation and engagement. Additionally, some students may not have access to the devices or internet connections required to use these systems effectively.
Another problem with relying heavily on AI tools such as ChatGPT is that it can lead to a deterioration of critical thinking and problem-solving skills. If students rely too heavily on AI to produce text for them, they may not develop the skills necessary to complete writing tasks designed to enhance their writing abilities (García-Peñalvo, 2023; Gayed et al., 2022). Additionally, it has been found out that ChatGPT produces fake citations to sources which actually do not exist. Therefore, not only the content but also the sources that ChatGPT seems to refer need to be verified, which is a part of digital literacy competence (Redecker, 2017). Therefore, it is important to educate students on the limitations of AI and to encourage them to think critically about the information provided by these tools. Because ChatGPT does not yet have Internet access and was trained on data obtained from the Internet before 2021, it is unable to compose reliable responses about any events or information that occurred after 2021 (Trust et al., 2023).

Teachers also face challenges when using AI tools in education. While they can be useful, teachers should be aware that AI cannot replace human creativity and critical thinking skills. Professional development training can help teachers integrate AI tools into their lessons in a way that supplements specific teaching and learning processes. It is also recommended that a critical evaluation of AI tools including ChatGPT be incorporated into teacher preparation and development programs in order to get the utmost benefit from this technology in education (Trust et al., 2023).

There are some concerns about data privacy and security when using online-based platforms in education. Teachers and students should be informed about data privacy and security regulations, and security measures should be regularly checked to reduce risks (Kasneci et al., 2023). Despite these challenges, AI tools can be beneficial in language instruction if used sensibly.

Finally, the integration of technology into language learning has been found to improve students’ language proficiency (Warschauer & Matuchani, 2003), and ChatGPT is a tool that can support this integration. Instead of thinking of these resources as tutors, it may be more effective to think of them as “assistants,” which would allow more strategic integration (Kukulska-Hulme & Lee, 2020). Supporting Trust et al.’s (2023) suggestions, the use of these tools must be done morally and ethically; and educators, administrators, and lawmakers should actively endeavor to educate themselves and their pupils on this topic.

REFERENCES


Reading List: Electronic Sources

A Teacher’s Prompt Guide to ChatGPT aligned with ‘What Works Best’ from https://drive.google.com/file/d/15qAxnUzOwAPwHzoaKBjd8FAgiOZYcKq/view?fbclid=IwAR2fRdl5gg4zU-81Fibj4BAOp5HqWHC_Ecy2sqKk4EiWX_L0Fka5GVz5dE
https://ditchthattextbook.com/ai-tools
https://medium.com/age-of-awareness/use-these-3-mindsets-to-discuss-ai-plagiarism-in-more-meaningful-ways-a6430de424ac
https://medium.datadriveninvestor.com/openai-quietly-released-gpt-3-5-heres-what-you-can-do-with-it-4dee2a438
https://myenglishdomain.com/chatgpt-prompts-for-language-learners/
https://www.ascd.org/blogs/leveraging-chatgpt-practical-ideas-for-educators?hsid=243344900&hsenc=p2ANqtz:-I4kXASSGaxKOPxcQSmagIFUSRIkXKSqD4SYogVszau1nZvF7cBbl2ouwJjb-7N7ggOcK8HVlQK8gxQK-8MwsUT_yw
https://www.the74million.org/article/the-future-of-the-high-school-essay-we-talk-to-4-teachers-2-experts-and-1-ai-chatbot/
https://www.timeshighereducation.com/campus/chatgpt-teaching-tool-not-cheating-tool?spMailingID=24568749&spUserID=EXEp0929629852328528579&spJobID=2715177255&spReportId=MjE3NTE3NzI1NQS2&hash=017317d8-ee8f-9af9c95d1
https://seths.blog/2023/01/the-end-of-the-high-school-essay/
https://www.insidehighered.com/views/2023/03/01/chatgpt-we-must-teach-students-be-editors-opinion
https://tomwhitby.com/2023/02/02/chatgpt-kill-it-or-use-it/
https://rachelarthurwrites.com/2023/04/24/ai-tools-for-teachers/
https://twowritingteachers.org/2023/04/27/a-few-ways-to-use-chatgpt/
Misuse of AI (Artificial Intelligence) in Assignments:
Can AI-Written Content Be Detected?

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In recent years, there has been a growing concern about the use of AI software, and some educational institutions are even beginning to ban AI software from mitigating these risks. However, some scholars and researchers are exploring the potential benefits of this technology, including improving self-reflection, critical thinking, and inquiry practice. In the last few months, the recent advances in Artificial Intelligence (AI) have led to an increase not only in teachers’ and learners’ use of AI-based tools and websites for language learning and teaching but also in worries about AI-written content. One of the existing challenges is using ChatGPT in writing and using the output produced in learner work without acknowledging the human contribution. Learners can use AI tools to create written assignments and gain an unacceptable advantage over other learners, which will also raise concerns about the educational equity. The current chapter aims to provide a brief review of AI-written content detectors. In addition, the chapter will also point out the benefits and limitations of using these content detectors and some implications. Some words of caution while using them since their reliability might vary and lead to false positives.

INTRODUCTION

In the past, people tended to be consumers of knowledge; however, with the introduction of blogs, social media, and Learning Management Systems (LMS), they have also acquired the role of content producers for readers worldwide (Well, 2023). Moreover, new possibilities have emerged for content creation with new technology, such as Artificial intelligence (AI) and specially-made software capable of processing information and imitating human skills (Baidoo-Anu & Owusu Ansah, 2023). AI applications can be used in various fields, such as medicine, education, and business. It has long been in computer science, including machine learning and adaptive technologies. The recent surge in the popularity of AI can be attributed, in part, to the emergence of innovative tools such as ChatGPT and MidJourney. These tools can generate content, text, and images from basic prompts, often at little or no cost. However, there is a debate surrounding the use of AI in education since educators worry it might suppress human intellectual efforts and encourage cheating (Cotton et al., 2023; Stokel-Walker, 2022). Since AI technology, such as ChatGPT, Microsoft Bing, and Google Bard, can be used to create content that can be submitted as human assignments, educational institutions in many countries for example Italy have started banning AI software. The purpose is to mitigate risks such as concerns over AI-written content, academic honesty, and educational equity. However, some scholars and researchers are exploring the potential benefits of this technology, including improving writing literacy and providing feedback (Tlili et al., 2023; Yan, 2023).

RESEARCH REVIEW

Technological advancement revolutionized the world of science with the release of ChatGPT. ChatGPT, https://chat.openai.com, is a system that uses statistic models of natural language processing (NLP) to generate an artificial text with human-like features that can have diverse forms like papers and poems, sequences of programming code or even
voices (Cotton et al., 2023). Although the first attempts were already conducted in 2021, the integration of chatbots into the educational process in tertiary education in 2022 (Kooli, 2023) provoked considerable debate on the potential opportunities and threats of its use. At the beginning, it is worth emphasizing that the technological development regarding artificial intelligence is very dynamic. Thus, the very mechanism of its functioning is still the subject of many scientific and technological debates. However, as a response to non-ethical behaviors, attempts have been made to design a system enabling modified text detection (Kooli, 2023). Both the AI itself and the detectors of its use are based on a system of algorithms, which at this stage is still in the development phase. The more so that the detectives have to keep up with the system capable of “self-learning”. According to the research described by Sadasivan et al. (2023), developing vulnerable tools for identifying AI-written content is still impossible due to the constantly improving ability of ChatGPT to imitate human-like texts. Another important limitation of is again AI-written content detectors a relatively short time of use and still limited number of data enabling the flawless functioning and can lead to false positive results (Gao, 2021; Kooli, 2023). All in all, the effectiveness of detectors depends on many variables such as domain, text type, etc. Nevertheless, their effectiveness, despite the fact that they do not give complete fullness, turns out to be greater than the antiplagarism methods used so far (Sadasivan et al. 2023).

**IMPLICATIONS**

In the last few months, the recent advances in Artificial Intelligence (AI) have led to an increase not only in teachers’ and learners’ use of AI-based tools and websites for language learning and teaching but also in worries about AI-written content, especially the use of ChatGPT. As a response to detecting the content produced by AI writing tools, several tools have emerged, including AICheatchCheck (https://www.aicheatcheck.com), GPTZero (https://gptzero.me), and Corrector App (https://corrector.app/ai-content-detector) in order to check the authorship of the given text. These websites or applications can predict whether a piece of writing, be it a paragraph or essay, has been written by an AI-based tool or a human. Table 1 provides a list of current AI-written content detectors.

**Table 1**

<table>
<thead>
<tr>
<th><strong>AI-written content detector</strong></th>
<th><strong>URL</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>AICheatchCheck</td>
<td><a href="https://www.aicheatcheck.com">https://www.aicheatcheck.com</a></td>
</tr>
<tr>
<td>AI Writing Check</td>
<td><a href="https://aiwritingcheck.org">https://aiwritingcheck.org</a></td>
</tr>
<tr>
<td>Content at Scale’s AI Detector</td>
<td><a href="https://contentatscale.ai/ai-content-detector">https://contentatscale.ai/ai-content-detector</a></td>
</tr>
<tr>
<td>CopyLeaks AI Detector</td>
<td><a href="https://copyleaks.com/features/ai-content-detector">https://copyleaks.com/features/ai-content-detector</a></td>
</tr>
<tr>
<td>Corrector</td>
<td><a href="https://corrector.app/ai-content-detector">https://corrector.app/ai-content-detector</a></td>
</tr>
<tr>
<td>GLTR (Giant Language Model Test Room)</td>
<td><a href="http://gltr.io/dist/index.html">http://gltr.io/dist/index.html</a></td>
</tr>
<tr>
<td>GPT Essay Checker</td>
<td><a href="https://ivypanda.com/gpt-essay-checker">https://ivypanda.com/gpt-essay-checker</a></td>
</tr>
<tr>
<td>GPT Zero</td>
<td><a href="https://gptzero.me">https://gptzero.me</a></td>
</tr>
<tr>
<td>Hugging Face GPT2 Detector</td>
<td><a href="https://huggingface.co/spaces/openai/openai-detector">https://huggingface.co/spaces/openai/openai-detector</a></td>
</tr>
<tr>
<td>OpenAI Text Classifier</td>
<td><a href="https://platform.openai.com/ai-text-classifier">https://platform.openai.com/ai-text-classifier</a></td>
</tr>
<tr>
<td>Originality</td>
<td><a href="https://originality.ai">https://originality.ai</a></td>
</tr>
<tr>
<td>Turnitin AI Writing</td>
<td><a href="https://www.turnitin.com">https://www.turnitin.com</a></td>
</tr>
<tr>
<td>Writer AI Content Detector</td>
<td><a href="https://writer.com/ai-content-detector">https://writer.com/ai-content-detector</a></td>
</tr>
<tr>
<td>ZeroGPT</td>
<td><a href="https://www.zerogpt.com">https://www.zerogpt.com</a></td>
</tr>
</tbody>
</table>
These tools vary and are limited regarding word limitations and uploading files. While most tools provide free service or some pose some limitations regarding the number of words to check and the use of documents to be uploaded, some, such as Originality and Turnitin AI writing, require paid versions only. While several tools, such as OpenAI Text Classifier, do not limit the number of words to be checked, several other tools might pose limitations. For example, AI Writing Check has a 400-word limitation; Corrector allows 600-word texts to be checked. However, GPT Essay Checker has a 4500-character limitation, and Content at Scale’s AI Detector has 25,000 characters (3846 – 5000 words). GPTZero also has a limitation in the GPTZero Classic version, with a 5,000 character limitation per document.

Moreover, there is a three-file limit per batch upload, which accepts pdf, docx, and txt file types; however, despite these limitations, it is stated that it will be free of use. Writer AI Content Detector can check texts up to 1,500 characters and also allows using URLs. ZeroGPT allows, on the other hand, a 50,000-character limit on texts and allows uploading files. Moreover, it checks texts for Open AI and Bard detection.

Teachers and learners are advised to remember that AI-written content detectors might be helpful to detect with a specific limit of accuracy or percentage. In other words, as indicated by these tools, they might indicate how likely or unlikely given text is written by a human and an AI entirely or partially. Moreover, it cannot be claimed that they are fully reliable. Therefore, they cannot be used as the only decision-making instrument to determine and decide whether a human or an AI writes the content. For example, the detector created by OpenAI, OpenAI Classifier itself, cannot always detect produced by ChatGPT, which the same company has created. Moreover, as indicated by Kirchner et al. (2023, para. 2), this classifier “identifies 26% of AI-written text (true positives) as “likely AI-written,” while incorrectly labeling the human-written text as AI-written 9% of the time (false positives)”. Similarly, AI Writing Check, which Quill and Commonlit have developed, can be accurate 80 to 90% of the time, meaning that ten to twenty percent of the content submitted to this website to be checked can be identified as false positive.

Another vital point to consider is that AI-written content might become more advanced, making it more difficult for these AI-written content detectors to distinguish between human-written and AI-written content. As the technology develops, AI-based tools might be trained on vast amounts of data, and their abilities might be advanced to the extent that the content produced by these tools might be identical to what might be written by humans. At the same time, AI-written content detectors might benefit from AI technology to improve their detection abilities. This will lead to a cat-and-mouse race, in which AI technology will produce more sophisticated and challenging to detect. At the same time, AI-written content detectors will constantly adapt and improve to keep up with these advancements to detect the content.

These have been attempts that have already started to make AI-written content look as if a human wrote it. These include minor modifications to the text, adding spelling mistakes, replacing some words with synonyms, or combining several sentences by conjunctions so that the sentences are compound-complex types to avoid detection or bypassing it. Several websites claim that they made some changes in the AI-written content, which will be rated as AI-written in a detector. These include GPT-1 (https://www.gptminus1.com), GPTInf (https://www.gp INF.com), and Undetectable (https://undetectable.ai). For example, GPT-1 detector such as GPTZero, it might be rated as “Your text is likely to be written entirely by a human.”

Teachers should also create awareness about the ethical use of AI technology. We must consider the ethical implications of deceiving readers into thinking that AI-written content is human-written. However, there may be valid uses for AI-written text, such as translation or creating summaries for study and exercise purposes. Rather than ignoring AI technology and pretending it does not exist, teachers should introduce AI technology into the classroom by talking about its use. For this purpose, several institutions have prepared online materials. For example, Commonlit and Quill (2023) have prepared “A Toolkit for Addressing AI Plagiarism in the Classroom”, which might be used to discuss issues such as academic integrity and the use of AI technology. In addition, DAY OF AI curriculum provides online materials and lessons that can be used to introduce AI technology to learners at all grade levels and ages from five to eighteen, which is available at https://www.dayofai.org/curriculum. Turnitin has also prepared a website dedicated to resources and guidelines regarding the issues and solutions for academic integrity solutions in teaching, learning, and assessment, available at https://www.turnitin.com/resources/academic-integrity-in-the-age-of-AI. In this way, learners can be introduced to AI technology and be provided with information on how AI technology can be used in writing assignments, how they have used AI tools in writing these assignments, and how to disclose this information. Academic integrity can be maintained by including an academic integrity statement for written essays. For example, in the assignments, students can pledge, “I affirm that I have not given or received any unauthorized help on this assignment, including AI-written content, and that this work is my own.”
The privacy of texts and personal information might also be a concern for both teachers and learners. Teachers and students might carefully consider the privacy policy of the website they will use to check texts for AI detection. They should be aware that by using these websites, they consent to the privacy policy and agree to its terms such as the use of uploaded texts to improve the language models. For example, ZeroGPT indicates that texts uploaded by users are not saved or made available online for other uses and that they do not use these texts to train and improve their AI detection model. However, personal information might be used and stored regarding how the website is used, the choices made, and the products selected.

It is also due to note that AI tools are not meant to be used by learners or students but at the same time by teachers. Teachers can now produce AI-written lesson plans, create rubrics and questions for formative and summative assessment, and many other possibilities (e.g., https://fltmag.com/chatgpt-design-material-exercises). Moreover, teachers can now use AI technology to provide feedback on student work. Therefore, teachers should also inform their students of their use of AI while assessing content or providing feedback to learners.

As for the steps that can be taken to reduce the over-reliance on AI-written content, teachers can utilize a variety of ways. These might include being flexible with (late) submissions, focusing on the process rather than the product, multiple draft assignments (proposal, interim drafts, feedback), using assignments or tasks related to the course content and lectures, and the recent events in a local and worldwide context, and short presentations on the assignment assignments/projects, or benefiting from alternative assessment tools such as creating posters.

In conclusion, while AI-written text detection has improved, it can be stated that the detection of AI-written content may not always be reliable and perfect since there is always the risk of false positives or negatives. Teachers are therefore advised to allow learners to demonstrate their understanding in a controlled environment and to use these tools in conjunction with human review and other forms of analysis to ensure the accuracy of identifying the content as either human or AI-written. Moreover, in these cases, learners should be allowed to demonstrate their understanding and knowledge, which can help minimize the risk of misidentification and ensure the overall quality of the content.

REFERENCES


APPENDICES

Readers should refer to the following books and articles for further reading.


CONTENT AREA FOCI
In this chapter we share results from over 16 years of research on the interplay of technology and active learning in the mathematics classroom. This research was conducted jointly by a mathematics educator and an educational technology specialist. This collection of research has many lessons for classroom teachers of mathematics to help them use technology to enhance the mathematics classroom. The research and corresponding results are shared in a way that gives teachers of mathematics practical take-aways for their classrooms. Additional resources are provided for teachers wanting classroom resources as well as for teachers wanting to learn more about how technology can play a role in an active learning mathematics classroom. Grouping students, using manipulatives such as TACTivities (tactile learning activities), engaging students with free collaboration technology tools, using mathematics-specific content tools, case-based learning, and a flexible, cooperative workspace are some of our research-based suggestions for teachers we elaborate on in this chapter.

**Keywords:** active learning, technology integration, mathematics, TACTivities, tactile learning

### INTRODUCTION

Technology use in the classroom has been studied for some time; however, research showing the effectiveness of active learning (Laursen et al., 2014) with the ever rapidly changing use of technology (LaRose & Talbert, 2016) prompted a collection of studies by our research group. This chapter illustrates the practical take-aways for mathematics teachers from our studies (Hodge et al., 2016; York & Hodge, 2015). The research began years ago in studying student perceptions of online homework systems (Hodge et al., 2009). Over the years, we became more interested in active learning in mathematics classrooms, especially given the fact active learning was showing to help under-represented groups perform better in mathematics classrooms (Laursen & Rasmussen, 2019). We became curious as to how instructors supported student learning of mathematics through technology-enhanced active learning mathematics classrooms. Surprisingly, we determined instructors who engaged their students on a regular basis rarely used technology to make the classroom more active (Hodge et al., 2016). Hence, we modified our original research to understand how mathematics instructors were using technology while teaching (not just for email, grading, etc.) in their classrooms and to understand the reasons many instructors were using technology in superficial ways (rather than to enhance the level of student engagement in the classroom). This has led us to explore how technology use can facilitate active learning in a mathematics classroom. By sharing our findings, we intend to help teachers improve their instructional practices in the classroom. We provide ways to integrate technology in a mathematics classroom in ways that engage students in mathematics.

### RESEARCH REVIEW

A number of mathematics teachers use a variety of active learning strategies in mathematics courses (Braun et al., 2017), two of which are inquiry-based learning (Ernst et al., 2017) and inquiry-oriented instruction (Laursen & Rasmussen 2019). When using active learning in mathematics a teacher does not have to incorporate technology to be suc-
cessful; however, thoughtful integration of technology in an active learning classroom can enhance the learning (Wang, 2020). We do not recommend merely using technology to make things better, faster, and easier, but instead to do tasks that would otherwise be unachievable without technology. We also feel technology should be integrated versus simply being used. How can we help students to really understand the mathematics they are learning (rather than plugging numbers into formulas to get an answer)? How can mathematics classes be changed for the better using the combination of technology to make the mathematics classroom a more active learning classroom?

The terms inquiry-based learning, inquiry-oriented instruction, and active learning may have different meanings to researchers and teachers. For simplicity’s sake, from here on in, we will use the term active learning as an umbrella term for all three. We base our definition of active learning on Laursen and Rasmussen’s 2019 definition of active learning, where they discussed the similarities among different inquiry-based learning strategies. They conceptualized these as the four pillars of inquiry-based instruction: a) collaboration for comprehension, b) engagement with challenging and meaningful mathematics, c) teachers delving into student thought process, and d) equitable teaching approaches (Laursen & Rasmussen, 2019).

IMPLICATIONS

We feel the best part of a conference, workshop, or paper is when teachers can take the ideas they learned and immediately implement them in their classroom. Hence, in this section, we will give practical ideas determined from our research that can be used in any mathematics classroom. We will do so in a question/answer format for ease of reading and so the reader can come back to these questions at any time for the take-aways.

What are some learning strategies to help foster student collaboration and engagement with both technology and mathematics? For your classroom setup, we suggest spaces that encourage collaborative learning and provide a welcoming environment. Mathematics can be intimidating enough, but if the classroom is warm and inviting it can help put students at ease (Hodge et al., 2019). We suggest tables versus desks, vertical whiteboards for students to share their work visually (Liljedahl, 2020), and having the students use either pencils or erasable markers so no work is permanent (and mistakes are encouraged and each to fix; see productive failure resources below). If technology is available, then larger monitors or displays per table, so everyone can see what is being produced.

Letting students know it is ok to make mistakes in mathematics helps support an atmosphere where students are willing to engage in their lessons. Technology is a great way to allow this to happen. Students, for example, can “undo” what they do when using most technological tools. Having an “erase,” “delete,” or “move” feature as part of the active technology you are using is encouraged. We call this concept, as it has been researched, productive failure (Kapur, 2014) and provide additional resources on this topic below. Essentially, productive failure is making a mistake and learning from it. For example, a student may try solving a problem using a guess and check method. If their answer is not correct, they can learn from what they did wrong to make a better estimated guess that helps them get closer to the correct answer. Hence, they learned from their mistake resulting in productive failure.

Having students use “think/pair/share” to work on a mathematics problem or educational question” is an excellent method to encourage students to first think on their own and then also to collaborate with their peers (Hodge-Zickerman, York, et al., 2021, p. 14). To do this think/pair/share strategy, the teacher asks a question of the full class. Then the teacher gives a few minutes for the students to try the problem on their own. Finally, students pair up to share their individual thinking with at least one other student. The teacher may choose to bring the class back as a full group to share ideas.

Having students work in groups (preferably 2–4 students) also supports the collaboration aspect of active learning (Golden, 2020). “As the students work together in groups, instructors can then ask the students questions about how they arrived at their answers that probe student thinking” (Hodge-Zickerman, York, et al., 2021, p. 12). Grouping students affords teachers an ability for “breaking large tasks into smaller chunks, maximizing time management, making use of peer feedback and assessment, challenging preconceived ideas, facilitating the development of communication skills, increasing achievement using groupthink, enhancing interpersonal skills, increasing opportunities to learn from one another, increasing resources available for students, and bringing together people with different skills/abilities” (Hodge-Zickerman, York, et al., 2021, p. 10).

For all the above ideas, consider using free technology tools such as Padlet, Menti, Google tools, Pear Deck, or Popplet. These tools, for example, can be used to engage students by posing questions to the students that make students think about mathematics before or after doing mathematics problems. Since there are so many free tools out there, it does
not hurt to check with your colleagues to see what tools are working for them (and new tools emerge everyday… ChatGPT anyone?). See Appendix A for more descriptions of each of these great tools as well as others.

What mathematics content specific technologies are available to teachers who want to actively engage students in mathematics? Teachers wanting to make their classrooms more engaging can do so with the help of technology. Desmos, Geogebra, GeogebraTube, mathematics applets, pattern block applets, PhET (a tool for mathematics and science learning), and even virtual manipulatives can bring “hands-on” learning to all classrooms. These free sites help in rural areas where supplies are limited, in virtual learning environments, and in classrooms where students just enjoy technology. We share our favorite free sites in Appendix A. Many of these allow teachers to create lesson plans and a classroom where they can see students working in real time.

One example of how Desmos can be used to make the mathematics classroom more engaging is to use the Desmos Activity Builder. Desmos Activity Builder has premade lessons as well as a free platform for teachers to create activities that use technology to promote rich engagement with mathematics. For example, Desmos has a premade activity where calculus students see the graphs of a function, its derivative, and its second derivative. In this activity, students drag and match the function name to the graph of the function (and similarly for the derivative of the function and the second derivative of the function). Then the students describe how they chose the labels. This is a very quick example of an activity that uses technology to get students thinking rather than using technology to calculate a procedural mathematics problem quickly. We encourage readers to explore the Desmos Activity Builder site and to create their own activities.

What types of problems lend themselves to active, engaged learning with technology? Case-based problems can be pedagogically great for the mathematics classroom. Problems can be presented using text-based or video-based cases to examine, scenarios to act out, etc. They require students to think about solutions rather than memorizing one solution path. These are also nice problems to practice productive failure with students.

TACTivities are “a portmanteau of the words tactile and activity. A TACTivity is a tactile learning activity” (Hodge-Zickerman, Stade, et al., 2021, p. 296). For us, “this means not physical props, but pieces of paper—or electronic equivalents—that may be repositioned, linked, matched, sorted, and so on to answer questions and solve problems embodied within the activity itself” (Hodge-Zickerman, Stade, et al., 2021, p. 296). TACTivities (both virtual and in person) are a good strategy to get students actively thinking about mathematics in a fun, game-like setting. TACTivities are activities that involve movable pieces, are often self-checking (e.g., a complete circle is formed once pieces are in correct order), no permanent moves, very few (if any) directions needed, actively engages students, typically completed in groups to encourage collaboration and engagement (Hodge-Zickerman et al., 2020). “When using TACTivities, students must communicate, explain their thinking, think outside of the box, discuss and learn concepts in such a way the conceptual understanding of mathematical ideas is developed without obstructing the learning of procedural skills” (Hodge-Zickerman et al., 2020, p. 379). See the TACTivity papers and resources listed below for examples of TACTivities and more ideas on how to incorporate them into the mathematics classroom both in-person and virtually.

Manipulatives, by definition, are “An object—physical or virtual—that can be moved around, or otherwise engaged with in a tactile manner, a part of a learning exercise or activity.” (Hodge-Zickerman, Stade, et al., 2021, p. 295). TACTivities are one example of a manipulative that can be used at home or in school to conjure more creative thinking (Hodge-Zickerman, York, et al., 2021).

Where can someone find more information about these teaching ideas related to technology and active learning in the mathematics classroom? We encourage teachers to visit the websites and blogs in Appendix B to learn more about active learning, technology, and the interplay of the two. We urge teachers to read the references provided, as many of them are accessible to any mathematics teacher (even though some are research articles). We are also available via email to discuss any ideas in our paper and offer both in-person and virtual workshops for teachers wishing to use technology to enhance their mathematics classrooms.
REFERENCES


Golden, P. (2020). The effects of small-group collaboration on student attitudes towards mathematics. [Undergraduate theses, Bellarmine University]. https://scholarworks.bellarmine.edu/ugrad_theses/46


APPENDIX A

Our favorite technology tools:

• [https://www.desmos.com](https://www.desmos.com) (free graphing and activity building tool)
• [https://www.geogebra.org](https://www.geogebra.org) (free resource for geometry)
• [https://www.coolmath4kids.com/manipulatives/pattern-blocks](https://www.coolmath4kids.com/manipulatives/pattern-blocks) (free pattern blocks for learning fractions)
• [https://www.didax.com/math/virtual-manipulatives.html](https://www.didax.com/math/virtual-manipulatives.html) (several free virtual manipulatives)
• [https://toytheater.com/category/teacher-tools/virtual-manipulatives](https://toytheater.com/category/teacher-tools/virtual-manipulatives) (several free virtual manipulatives)
• [https://mathigon.org/polypad](https://mathigon.org/polypad) (free tool for everything from geometry to probability/statistics)
• [Padlet](https://padlet.com) (a free online whiteboard or bulletin board for brainstorming, collaboration, and posting ideas. Padlet calls itself a “wall”)
• [Menti](https://menti.com) (with Mentimeter you can create online presentations that show the results of polls live. Results can be viewed as word clouds that change in real time as more responses are input.)
• [Google](https://support.google.com/a/answer/7370133?hl=en#refined:features%20and%20enhanced%20administration%20controls) tools (there is a suite of tools just for education: [https://support.google.com/a/answer/7370133?hl=en#refined:features%20and%20enhanced%20administration%20controls](https://support.google.com/a/answer/7370133?hl=en#refined:features%20and%20enhanced%20administration%20controls))
• [Pear Deck](https://peardeck.com) (an interactive presentation tool and an add-on to Google Slides)
• [Popplet](https://popplet.com) (an interactive mind-mapping tool)
APPENDIX B

For more readings and resources, see:

Active learning materials for first semester calculus. (n.d.). Available at https://math.colorado.edu/activecalc1/index.html. This website has both interactive in-class worksheets as well as samples of TACTivities for the precalculus through calculus II classroom.


Discovering the Art of Mathematics. (n.d.). Available at https://www.artofmathematics.org/. This website not only explains what active learning is, but it also gives sample classroom videos to see active learning in action. Resources for the mathematics classroom are also provided.


Julia Robinson Mathematics Festival. (n.d.). Available at https://jrmf.org/puzzle. This website has interactive technology resources related to mathematics and problem solving and puzzles. Logic, shape, and number are all addressed. There is also a Spanish option. These puzzles go beyond memorization and simply following mathematical rules to getting students to use technology to think deeply about mathematics.


This article offers further insight on how technology can go hand-in-hand with an active learning mathematics classroom.
Visual computing is the set of technologies developed and used in relation to visual content and includes topics like artificial intelligence, machine learning, computer graphics and computer vision. In order to support middle school teachers’ use of visual computing, we recommend the use of visual computing apps contextualized with standards–driven subjects like mathematics. Providing meaningful experiences with visual computing will motivate and inspire students early in their education to seek experiences using a variety of technological tools with different features and affordances. Middle school lesson guidance is provided using free technology apps emphasizing explorations in mathematics using visual computing technology. The technological tools include Pixilart and Tinkercad.

INTRODUCTION

Visual computing is defined as “a set of technologies that process or generate visual content or visual information” (Segura et al., 2020, p. 3). Visual computing includes a plethora of technological advances including artificial intelligence (AI), machine learning and computer vision and graphics (Li & Shi, 2018). In particular, we wish to emphasize that not all visual computing leverages AI (e.g., traditional graphics rendering for movies), and alternatively not all AI is focused on visual computing (e.g., natural language processing and chatbots). Despite the influx of visual computing in our daily lives, these technological advances have permeated society, but have largely been left out of K–12 curriculum and instruction. There has been a recent push to include applications of AI, including those which fall under the domain of visual computing, within the K–12 educational system. The continued focus to develop and refine lessons to better prepare students for the inevitable technological evolution and growth has been encouraged (Williams et al., 2022). Recently, AI4K12 (https://ai4k12.org/) was formed and is in the process of designing guidelines to support the teaching of AI in schools, including those AI concepts that intersect with visual computing. Despite these efforts, AI, visual computing and other more advanced technologies are not commonly used in the classroom.

To support middle school teachers’ use of visual computing in the mathematics classroom, we provide direction regarding how to integrate the content using free, online applications. Guidance is contextualized to support integrated science, technology, engineering and technology (STEM) learning. Two visual computing–based middle school mathematics lessons are offered. In the first lesson, Pixilart (www.pixilart.com) is used to build images with specific mathematical ratios. In the second lesson, Tinkercad (www.tinkercad.com) is used to contextualize the building of probability games.
with specific outcomes. Both of these lessons encourage the use of visual computing through the use of free online applications.

RESEARCH REVIEW

Over the past 20 years, there has been a distinct, prominent, and defined push toward integrating STEM in the K–12 classrooms (rather than teaching each subject in isolation) (Allina, 2018; Quigley et al., 2020). Despite that push, there has been a history reflecting a lack of meaningful technological experiences in United States schools (Nelson et al., 2019). Teachers generally support the use of technology, but struggle with seamlessly integrating technology into STEM content (Liu & Kleinsasser, 2015; Tondeur et al., 2017). One of the ways to improve teachers’ technology use is through the development and modeling of innovative, easy to implement activities that do not require a lot of training, expense or equipment.

One method of incorporating visual computing into the mathematics classroom is through the use of intelligent tutoring or through AI–driven feedback (Davis et al., 2020; Murphy, 2019). However, we recommend a more nuanced use of technology in which learners get the opportunity to explore the features and affordances of the technology while attending to content standards (Gadanidis, 2017). In other words, learners should be actively involved using the technology, moving beyond getting feedback and guidance through intelligent tutoring. Games, apps and technologies are becoming more widespread and offer a contextualization for curricular explorations across a variety of subjects (Lin & Van Brummelen, 2021; Su & Zhong, 2022).

IMPLICATIONS

The synergetic integration of technology including computer graphics, machine perception, image processing and imaging technology are components of visual computing (Diaz et al., 2016). Specific technologies emphasizing visual computing are used to encourage middle school students to create images and/or art with specific mathematical conditions. These applications can support a plethora of mathematical explorations. The sites are user friendly and users can begin exploring right away. Several activities are described within each of the visual computing applications that use algorithms to represent and process images. Each activity is aligned with the Common Core State Standards for Mathematics (CCSSM; National Governors Association, 2010).

Pixilart

Users create pixelelated images and art using Pixilart (www.pixilart.com). Pixilart emphasizes how pixels form the image content. Pixilart provides an interface where students can create images on a pixel plane. A variety of options are available for drawing. For example, the width of the drawing tool is adjustable and there are a variety of available colors.

Activity One. For this first activity, students develop a probability model using Pixilart. Students create pixel–based images; they can focus on abstract images or images that are constructed using a specific ratio, see Appendix A: Designing Ratios Using Pixilart. Figure 1 is a potential solution to the first image of the worksheet in Appendix A: Designing Ratios Using Pixilart. Figure 1 is a potential solution to the first image of the worksheet in Appendix A. The lesson aligns with proportional reasoning standards of the CCSSM, 6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities (National Governors Association, 2010).
Activity Two. For this activity, students explore and compare the standard coordinate panel and quadrants to the pixel plane. Students can graph points on the coordinate plane in all quadrants. Students can graph lines or points (or draw a picture) and compare how pixels are placed comparing it to the coordinate plane. Students can be asked: How is the coordinate plane similar/different to the Pixilart canvas? Graph a polygon in each quadrant in a standard coordinate plane. How would each polygon’s points need to be adjusted to be graphed in a Pixilart canvas? Create an algorithm to convert a shape from each of the standard quadrants to a Pixilart plane. This lesson aligns with the number system standard of the CCSSM: 6.NS.C.8, Solve mathematical problems and problems in a real-world context by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

Tinkercad

Tinkercad (www.tinkercad.com) is a graphics interface to represent three-dimensional shapes. Tinkercad centers on the use of three-dimensional shapes, geometry and simulations. There are templates available for students to alter or use as designed. The simulations can connect to engineering and science. Students can design or alter a given marble mazes, dominoes, pachinko boards, straw roller coaster tracks, Galton boards and catapults (among others), see Figure 2. The simulation lab includes three-dimensional designs, circuits and code blocks.
**Activity One.** Probability is commonly taught in mathematics using spinners, dice and perhaps a deck of cards. Fair and perhaps unfair games are explored or designed using these hands-on manipulatives. In this activity, this common approach is extended using visual computing. For this activity, students use the free website Tinkercad to design games with specific probabilities of winning. Imagine you are designing a game for a carnival that involves rolling a ball through a pathway. The player selects one of four pathways, then rolls the ball. If the ball exits, the player wins. If the ball hits a wall, the player loses. The routes of the pathways cannot be seen by the player, only the entry and exit points, see Appendix B, A Probability Design Challenge using Tinkercad. The lesson aligns with statistics and probability standards of the CCSSM: 7.SP.C.7 Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy.

**Activity Two.** Data analysis is one of the middle school subjects that include concepts such as mean, mode, and median. To explore these ideas of measures of center, students might formulate questions that require data analysis by developing educational activities (or games). A Tinkercad simulation is used to integrate phenomenon and events that require collecting and organizing data by constructing bar charts. In this activity, this common approach is extended using visual computing technology. Using a Tinkercad ready-built simulation, students are provided three transparent plastic buckets which are fixed to the wooden poles. The player throws the given toys; there is an interface within the Tinkercad app that allows the player to throw with 12 different types of toys at random into the left, middle and right buckets for a certain period of time (e.g., 90 seconds). During that time period, the player can make accurate throws as well as make missed throws. When the time is up, each group came together, and they organize the data they collect. The lesson aligns with statistics and probability standards of the CCSSM: 6.SP.A.2 Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape and 6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

Students virtually throw items into buckets see in Figure 3. When the time is up, each group came together, and they organize the data they collect. For the statements below, they find the values of mean, mode, median, lower quartile, upper quartile and interquartile.

- The average number of throws made to each bucket (Mean):
- The average number of toys that went into each bucket (Mean):
- The name of the toy thrown the most frequently to each bucket (Mode):
- The toy name that gets the most frequently into each bucket (Mode):
- Median value for toys that go into each bucket (Median):
- Median value for toys thrown into each bucket (Median):

The is a link to the simulation can be found here: (https://www.tinkercad.com/things/aXDU4s1d5KV?sharecode=jYB2ph4mt2HyhgpipKNGT-nZzwXkwpDWeXsU20-WNM).

**Figure 3**

*Screenshots from a Tinkercad simulation, throwing items into buckets (Kurban, 2023)*

| The three buckets | The screen shot taken after throwing some toys into buckets on the left, middle and right |
**Additional Resources:** In addition to the sample lessons presented in this chapter, we highlight the creation of a new resource for visual computing technology integrated with math, science, and other middle school standards: the ImageSTEAM program (www.imagesteam.org). This program contains sample lessons, videos for use by students and teachers, lesson guides/tutorials to support teachers, and “behind-the-scenes” videos discussing the creation of these lessons. Sample technologies leveraged include Google’s Teachable Machine, Tinkercad, and Pixlr.com. Other free apps and how they can be used in middle school mathematics can be found in Appendix C. We recommend interested readers to check out this resource and helping to contribute to the growing body of open-source curriculum.

**ACKNOWLEDGEMENT**

We would like to thank all the teacher and student participants of the ImageSTEAM program which helped inspire us to design new mathematics lessons using visual computing technology. This research was supported by the National Science Foundation’s Innovative Technology Experiences for Students and Teachers (ITEST) program under award numbers DRL–1949384 and DRL–1949493. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

**REFERENCES**


APPENDIX A

Designing Ratios Using Pixilart

Instructions: Using Pixilart, create an image with the given color ratio; colors are self–selected. Include a screenshot and answer the questions for each image. Website: [www.pixilart.com](http://www.pixilart.com)

<table>
<thead>
<tr>
<th>Image #1: Create an image has a 2:1 ratio of Color 1 to Color 2.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using measurements and numeric values, explain how your image meets the specific ratio requirements.</td>
</tr>
<tr>
<td>What is the ratio of Color 1 ________ to Color 2________? Explain your reasoning.</td>
</tr>
<tr>
<td>What is the ratio of land to the entire picture? Explain your reasoning.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image #2: Create an image that is  Color 1,  Color 2, and  Color 3, and the rest of the image is Color 4.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the ratio of each of the colors in relation to the total image? Explain your reasoning.</td>
</tr>
<tr>
<td>● Color 1________:</td>
</tr>
<tr>
<td>● Color 2________:</td>
</tr>
<tr>
<td>● Color 3________:</td>
</tr>
<tr>
<td>● Color 4________:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image #3: Create an image with the following ratios using the fraction strip below.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the ratio of each of the landscape features in relation to the total image? Explain your reasoning. Explain how to create the given ratio.</td>
</tr>
<tr>
<td>● Color 1________:</td>
</tr>
<tr>
<td>● Color 2________:</td>
</tr>
<tr>
<td>● Color 3________:</td>
</tr>
<tr>
<td>● Color 4________:</td>
</tr>
<tr>
<td>● Color 5________:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Image #4: Create an image with at least five different colors, each with a different ratio in relation to the entire image.</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the ratio of each color in relation to the total image? Explain your reasoning.</td>
</tr>
</tbody>
</table>
### APPENDIX B

**A Probability Design Challenge using Tinkercad**

Working in pairs, sketch your design below with each of the specific guidelines for the three gameboard. Sketch your gameboard first, then build your sketch using Tinkercad. Take a screenshot of each gameboard. Then, provide a written explanation (about five sentences) justifying how your gameboard meets the requirements. Be sure to use principles of probability (fractions and expressions) in your explanation. You will turn in: 1) three sketches, 2) three screenshots and 3) three explanations. Website:

| **Gameboard #1:** Design a gameboard with a probability of winning equal to with two possible winning exits |
|--------------------------------------------------|--------------------------------------------------|
| Sketch | Explanation |
| ![Sketch](image1.png) | ![Explanation](image2.png) |

| **Gameboard #2:** Design a gameboard with a probability of winning equal to |
|--------------------------------------------------|--------------------------------------------------|
| Sketch | Explanation |
| ![Sketch](image3.png) | ![Explanation](image4.png) |

| **Gameboard #3:** Design a gameboard by modifying one of the previously created gameboard and design a new gameboard with a probability of winning equal to |
|--------------------------------------------------|--------------------------------------------------|
| Sketch | Explanation |
| ![Sketch](image5.png) | ![Explanation](image6.png) |

| **Optional Gameboard #4:** For those of you who want an extension, design your own gameboard, explain how your game works (how does someone win or lose), take a screenshot and explain the probabilities of winning and losing. |
|--------------------------------------------------|--------------------------------------------------|
| Sketch | Explanation |
| ![Sketch](image7.png) | ![Explanation](image8.png) |
# APPENDIX C

## Free Apps to support Learning using AI and Visual Computing

<table>
<thead>
<tr>
<th>Name of App</th>
<th>Website address and Description of the App</th>
<th>Mathematically Aligned Activities</th>
</tr>
</thead>
</table>
| Scratch     | Available: [http://scratch.mit.edu](http://scratch.mit.edu)  
Scratch is the world’s largest free coding community, where students can use computational thinking and code to create stories, games, and animations using a block-based coding language. | Scratch can be used for scale models, analysis of geometric shapes and pattern analysis. Sample lessons can be found at: [https://ai4k12.org/activities/](https://ai4k12.org/activities/). |
| Teachable Machine | Available: [https://teachablemachine.withgoogle.com/](https://teachablemachine.withgoogle.com/)  
Google’s free online platform where anyone can build a machine learning model, with no code. Teach your computer to recognize images, audio, and more. | Students can program the Teachable Machine to identify features of geometric shapes or to identify linear, quadratic and exponential growth. |
| Pixlr | Available: [https://pixlr.com/learn/education/](https://pixlr.com/learn/education/)  
Pixlr is an online, browser-based, free photo editing software tool allowing many features from simple graphic design to advanced photo manipulation with layers, compositing, and AI object recognition. | Students can experience matrix activities or use operations (addition, subtraction, multiply and/or divide) to evaluate how these operations impact pixel values and images. Students can evaluate ratios and dilations. |
| Harmonics | Available: [https://musiclab.chromeexperiments.com/](https://musiclab.chromeexperiments.com/)  
Harmonics | Students can evaluate the audio waves using fractions, frequency, wave length and/or the relationship between them. |
| Code.org’s AI for Oceans | Available: [https://code.org/oceans](https://code.org/oceans)  
This animated web app activity teaches students to train an image recognition model to distinguish between animated trash and fish in the ocean. | Fully developed lesson plans for this app can be found here: [https://curriculum.code.org/hoc/plugged/1/](https://curriculum.code.org/hoc/plugged/1/). |
| Quick, Draw! By Google Creative Lab | Available: [https://quickdraw.withgoogle.com/](https://quickdraw.withgoogle.com/)  
This is a sketching game similar to Pictionary where a neural net tries to guess what is drawn by the student. This is a very quick and fun activity that is a great introduction to data and patterns in visuals. | Students can develop their own conjectures to test the app. For example, what features of the drawing impact the app’s accuracy and quickness? Does the accuracy of the drawing or quickness of the drawing have a greater impact the app’s ability to identify the image? |
Enhancing the Mathematics Curriculum With Technology

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Technology has become an integral part of the world we live in; however, students use technology in vastly different ways than educators did in their own youth. Therefore, educators must adapt and make the integration of technology a prevalent part of the mathematics curriculum, while simultaneously facilitating new learning opportunities. Technology use in the mathematics classroom can help influence students’ problem-solving skills while motivating them to extrapolate their learning to real-world situations. Such experiences also encourage students to tap into their creative potential. In searching for materials and methods to support the mathematics curriculum, educators should also look to enhance curricula through methods of substitution, augmentation, modification, and redefinition. Effective integration of technology into the curriculum should anticipate student needs and optimize student learning; it should enhance both the curriculum and teachers’ pedagogical practices. In this chapter, the authors describe enhanced mathematics instruction using several online resources.

INTRODUCTION

While school mathematics has remained relatively unchanged, the performance and experiences of students in the mathematics classroom has been in decline. Students lack growth as mathematical thinkers, relying on rote memorization and procedural mathematics as opposed to thinking critically and engaging in productive struggle to deepen mastery and understanding. As educators, the challenge has become to remedy these issues and help students develop into mathematical scholars.

Problem-posing is an essential part of productive struggle. Positive outcomes include “developing a sense of ownership of the mathematics, legitimizing asking questions, and fostering habits of mine that are conducive to the student of mathematics” (Lewis & Colonnese, 2021, p. 142). “Engaging students in mathematics learning that is purposeful and leads to productive disposition, requires the teacher to select suitably challenging tasks, appropriately implement these tasks, and then expect students to explain and justify their responses to the tasks” (Livy et al., 2018, p. 24).

The use of technology in the classroom can lead students “to more efficiently understand the different mathematical notions” (Joshi, 2017, p. 8). Therefore, it is imperative that education professionals use technology to improve the mathematical fluency of their students. This chapter provides a discussion of mathematics instruction that incorporates a variety of technological tools and pedagogical practices. It also includes ways to use those tools to support students’ development of significant mathematical content and practices.

RESEARCH REVIEW

Technology has become an integral and ubiquitous part of 21st century mathematics classrooms. The National Council of Teachers of Mathematics (NCTM, 2000) asserts that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (p. 24). Furthermore, research (e.g., Gadanidis & Geiger, 2010; Hegedus et al., 2015; Kastberg & Leatham, 2005; Nelson et al., 2009) has shown the strategic
use of technology supports students’ conceptual understanding, mathematical procedures and skills, problem solving, and reasoning. Technology can also help motivate students to transfer their learning to real-world and novel situations.

There has been an increase in the number of teachers receiving classroom technology training over the last five years (U.S. Department of Education, 2023). This coincides with an increase in students with home devices (e.g., computer, tablet) and internet access (U.S. Department of Education, 2023). However, many mathematics teachers and students still use technology primarily as a “simple calculational tool, or for data storage, or for the display of static materials, methods which are unlikely to develop student understanding, stimulate their interests, or increase their proficiency in mathematics” (McCulloch, 2018, p. 26).

There are inherent errors in how mathematics is taught. According to Liang (2016), “Too often, students are taught the content with little awareness of their own misconceptions and the reasoning behind the content” (p. 47). Using a variety of resources, effective implementation of technology can empower students by giving them control over their own learning which allows students to learn through discovery (Ruffini, 2012).

There are untold content-specific (e.g., Desmos, GeoGebra) and content-neutral (e.g., HyperDocs, Screencasting) technologies that can be used strategically in mathematics classrooms. Research suggests that such technology “strengthens mathematics teaching and learning . . . [and] keeps mathematics, and not technology, as the focus of instruction” (NCTM, 2015, p. 1). It is worth highlighting four specific tools. First, Pope (2023) asserts that both platforms, Desmos and GeoGebra, can increase student engagement and interest, foster a more student-centered, discovery-based classroom, and help students make sense of mathematical tasks and their solutions.

Second, teachers can create, design, and use HyperDocs—digital lessons that provide “students access to resources, and opportunities to collaborate, communicate, create and think critically” (Berg, n.d.)—as a student-centered learning module, station activity, and parent resources (e.g., Gonzalez, 2017). It can also be used as a means for students to learn from or with technology (e.g., Ertmer & Ottenbreit-Leftwich, 2013). Finally, HyperDocs can engage students in creativity, collaboration, communication, and critical thinking (Partnership for 21st Century Skills, 2007).

Last, screencasting can support mathematics teaching and learning in a variety of ways, including as a re-teaching tool, way to flip the classroom, resource for absent students, remote learning tool, means to provide feedback, formative assessment tool, and a way to hold students personally accountable (Mulamphy et al., 2010; Robinson et al., 2015; Soto & Ambrose, 2015; Thomas, 2017).

IMPlications

Challenging tasks and productive struggle lead to success in mathematics. Educators can seamlessly integrate productive struggle using the three-stage process of explore, launch, and summarize (Sullivan et al. 2015). Productive struggle begins with the teacher giving students a topic or task with which to work. In the first phase, teachers prompt students to identify a strategy or tool that will help them make sense of the task and work towards a solution. In the second phase, teachers provide cues for students to implement their identified strategies. Though students might encounter failure, productive struggle leads students to reexamine the problem and choose a new path. Finally, once the task has been completed, educators direct students to summarize their findings and note their mental processes throughout their solution of the task (Livy et al., 2018).

Technology should play a prominent role during instruction and can encourage students to engage in productive struggle and stimulate effective problem solving. Teachers should use conceptual conflict as a means to promote conceptual change in their students’ thinking. Educators can promote conceptual change in the classroom by helping students recognize, debate, and confront their own misconceptions, and by encouraging students to modify their thinking and accommodate new information and knowledge (Liang, 2016).

Desmos and GeoGebra can be used to help students confront their misconceptions about graphs and functions. There are innumerable, free teacher activities on both platforms. You can select a lesson or topic you are currently covering in class that would benefit from technological enhancement. You can also use the search feature to look for a specific topic or keyword(s). Explore the resulting activities by reading the instructions, walking through the demo-activity, viewing the selected slides, and documenting questions or prompts that would support students throughout their engagement with the activity. Desmos activities are straightforward, easy to access, and allow teachers to quickly decide the applicability of the activity. When managing the session, a live dashboard is available to monitor student progress, interact with students, and provide feedback. Such activities allow students to lead instruction, allowing the educator to provide support by answering questions, posing arbitrary prompts, and giving activity extensions or examples.
**Marbleslides** is an exceptional set of Desmos activities that feature both algebraic and transcendental functions to aid students in developing deep understandings of transformations of a parent function, including vertical and horizontal stretch and compress, reflections over both the x-axis and y-axis, and vertical and horizontal translations. *Marbleslides* allow the educator to guide students to struggle productively through the dynamic activity, resulting in a more robust understanding of transformations—as opposed to traditional paper and pencil graphing of equations. Prior to using *Marbleslides*, educators can demonstrate sliders to students, an activity that is conducive to modifying a typical “trial-and-error” process with random values. Students use sliders by replacing typical coefficients or numerical constants with a letter (other than x or y) within the standard form of an equation. Students can drag sliders throughout a range of values, or they can press the “Play” icon to see the graph transform. Students should be encouraged to use sliders so they can see changes in real time (see Figure 1).

**Figure 1**

*Desmos play activities prior to using marbleslides*

*Marbleslides* activities are accessible through the [Desmos Teacher](https://teacher.desmos.com) page, using the key word ‘*Marbleslides*’ (see Figure 2). The tutorials are simple and provide teachers with opportunities to preview and demo the activity. To begin activity, click ‘assign,’ which generates a code for the class activity. You can then monitor the activity and your students’ progress from the dashboard (see Figure 3). Once in the activity, students are free to explore, apply, and even collaborate with their peers.
Another beneficial activity on Desmos is the Polygraph Activity, which provokes students to analyze graphs, sparks discussion, and promotes collaboration (see Figure 4). After selecting the activity, students are paired up to play a game similar to “Guess Who.” Students are tasked with asking one another questions about the graphs in order to determine which graph their classmate has chosen. You can challenge students by providing prompts or suggesting features of the graph to explore, using transformations.
Teachers also have the autonomy to create their own projects in Desmos. One example is the Desmos Graphing Project, which can be used to extend and recreate students’ foundational knowledge of functions and graphs. By guiding students through a manifestation of creative license, the “emphasis on creativity, initiative, inquiry, and exploration, and independent work can captivate students’ interest and . . . [encourage] a deeper understanding of some mathematical concepts” (King, 2017, p. 37). Desmos Graphing Project activities can be used to reinforce student proficiency with families of functions and equations. Students are asked to design a picture using equations. This project provides students with an immense amount of creative discretion. You can give students additional structure by including compulsory requirements, such as the number and type of equations, as well as guidance on how to use sliders or restrict the domain and range. You can effortlessly differentiate this activity by course, grade and level of students, by tailoring to the specific needs of each student. Differentiation might include varying the required types of equations, the number of equations, and modifications in the design (see Figures 5 and 6 for examples).
GeoGebra holds a similar classroom resources section for teachers. Select ‘Resources’ to search for books or activities by topic, standard, or keyword (see Figure 7).

Figure 7
Image of GeoGebra classroom resources

GeoGebra Books resemble a physical book with various chapters to explore. Teachers can integrate GeoGebra Books into instruction as required “reading” or exploration prior to a lesson. Because these books are informal and exploratory, teachers must provide specific instructions, such as indicating which chapters students should explore, what prompts they should respond to, and which items students should screenshot and document as evidence.

GeoGebra activities are similar in nature and structure to activities in Desmos. Educators can either assign a GeoGebra activity directly to Google Classroom or run the lesson directly in GeoGebra (see Figure 8). If choosing to implement within the platform, students would select the classroom button on GeoGebra and enter the code generated by the activity.
An advantage to both Desmos and GeoGebra is that they are efficient, affordable, accessible, and dynamic, and enable students to focus on discovery. Although Desmos may hold the edge for its graphing calculator because it enhances what a traditional graphing utility can do, GeoGebra has the three-dimensional graphing calculator, which is useful in the following Conic Section Exploration (see Figure 9).

SECTION #2: Open the 3D graph in Geogebra: CLICK HERE

Some notes about 3D graphs: z is a third variable that represents an axis coming “off the page.” You can rotate/spin the image given. The planes you will be graphing are your traditional graphs on an x-y cartesian coordinate grid.

1. Type in the following equations for two 3-dimensional cones (see image):
   \[ z = \sqrt{x^2 + y^2} \text{ and } z = -\sqrt{x^2 + y^2} \]

2. Click the gear in the top right-hand corner and select “zoom to fit.”
Educators can further facilitate productive struggle by combining Desmos or GeoGebra with HyperDocs. It is very simple to create explorations through a HyperDoc, a document that has links to either Desmos or GeoGebra. The HyperDoc then leads students through an activity, with given prompts, directions, and open-ended guidance. Such tools can allow students to explore first and formulate later as they engage and explore on their own or in collaborative groups. Integrating HyperDocs gives students the opportunity to visualize, discover, and hypothesize, and provides space for student choice, creativity, and autonomy (Carpenter et al., 2020).

The following Polar Graphs Exploration (see Figure 10) is a HyperDoc—a dynamic document serving as a collection for prompts and screenshots of student work.

**Figure 10**

*Image of polar graphs exploration*

---

**POLAR GRAPHS EXPLORATION**

Open Desmos Graphing Calculator in a new tab: [CLICK HERE](#)

Directions: Using Desmos, graph the equations given. Take a screenshot and insert the image below the equation. Then answer the questions by typing in the box. On a chromebook, hold down together “ctrl” and “alt” and the double window button. Then, click the box with the plus and grab the part of your screen you need.

**Type 1: “CIRCLE”** \[ r = a \sin \theta \]

<table>
<thead>
<tr>
<th>( r = 4 \sin \theta )</th>
<th>( r = 5 \sin \theta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r = -2 \sin \theta )</td>
<td>( r = -8 \sin \theta )</td>
</tr>
</tbody>
</table>

Explain what you see?

How does the coefficient “a” affect the graph? Explain

Each graph is symmetric with respect to what line? (This is the line \( \theta = \frac{\pi}{2} \))

---

One strategy is to begin with creating tables, then inserting prompts. The document is finalized by inserting links, media, and vibrant images. The HyperDoc can serve as a fluid document in which students explore, strategize, and respond to teacher prompts. Explorations can be created in conjunction with Desmos or GeoGebra, or any integrated media. Using HyperDocs can be an essential part of a teacher’s repertoire and provides students with license to see mathematics live. Additionally, the ability to manipulate items is a profound resource for students to demonstrate conceptual growth in mathematics.

Similarly, Three-Act-Math Tasks can be used to solve real-life problems and promote the notion that much like life, mathematics can be messy (Lewis & Colonnese, 2021, p. 96). Essentially, the three acts include setting up a plan, developing and carrying out that plan, and comparing, revising, and extending ideas (Hallman-Thrasher, 2018). Graphing Stories directs students to write a story about a graph they observe in a video about an action or movement with respect to time. Throughout the activity, teachers can hold students accountable by posing questions and incorporating a dynamic HyperDoc, which serves as a means to collect data and allow for collaboration with peers and the teacher. At the conclusion of the activity, students are directed to revise their work and make connections to future applications. Such connec-
tions help to extend students’ thinking. This also helps students find value in the challenge and building of persistence, work ethic, and resilience. Such outcomes, no matter how difficult the task, are crucial for their success in mathematics.

Screencasting may be the most powerful tool at a mathematics teacher’s disposal. Mathematics might be a challenging content area for many students. It may also seem impossible for students to learn the material in such a short amount of time each day. This is particularly true when teachers ask students to listen at the same time, in identical ways, in the same format, each day. Screencasting can transform the mathematics classroom by giving students accessibility to instruction, flexibility, and choice. While the process of creating content can be challenging and includes a moderate learning curve, learning how to record and edit lessons, finding supplementary content, and making lessons instantaneously available can make differentiation more effective and harmonious. Integrating screencasting helps teachers redesign education by effectively incorporating blended learning and creating new opportunities for student learning (Engelbracht et al., 2020).

There are many screen-recording applications, with Screencastify (see Figure 11) being one of the most common. Screencastify even has a Chrome extension. Teachers simply click on the “arrow” icon in the toolbar to begin recording a part of the screen, whether a specific tab in the browser, the entire desktop, or just the webcam.

**Figure 11**

*Image of Screencastify Chrome extension*

While selecting what to record, there is a place to verify that the microphone and webcam are working properly. When all selections have been made, the user simply clicks the “Record” button. The recording can be temporarily stopped by clicking on the pause button. When finished, the video will automatically be uploaded to the Screencastify folder on Google Drive. Videos can then easily be moved to a different folder. At this stage, teachers can link to “Open in Editor” or send the file to trash. The video editing feature is straightforward and easy to use for even the most novice content producer, as illustrated by the Screencastify Video Editor video.

For teachers not able to create their own videos (e.g., time), mathematical instructional videos or tutorials can be easily accessed on YouTube and Khan Academy. Edpuzzle can also be used to either upload content or search the web for content. To begin, users simply choose the “add content” link, which provides four options: discover video content, upload video, record video, and student project.
“Discovering video content” peruses the web for videos, “Upload video” uses the teacher’s created content, “Record video” allows the teacher to record directly in Edpuzzle, and “Student project” creates an assignment for students to design their own video. Subsequently, educators can insert formative questions for students to respond to for the duration of the video (see Figure 12), which holds students accountable and allows them to learn productively (Courtney et al., 2022). Instruction can then be seamlessly assigned to students on a preferred learning management system.

Figure 12

Image of teacher created Edpuzzle video

Educators must be careful about the specific implementation of technology, by acknowledging that any form of technology is not a substitute for the role of the teacher. Rather, technology is meant to develop the educator and equip them with the tools to move their students forward as mathematical thinkers. According to Courtney et al. (2022), “the successful implementation of technology-based learning relies on the teacher first, followed by the technology used” (p. 9). As students progress through Bloom’s Taxonomy (Bloom, 1956) towards analyzing, evaluating, and creating, much the same is incorporated through the Substitution, Augmentation, Modification, and Redefinition (SAMR) method with Modification and Redefinition of a non-technology enhanced activity to become a technology enhanced activity (Puentedura, 2005). It is simple to substitute and augment a previous non-technology enhanced activity. The challenge is to wield technology to transform a concept or task. Ford (2018) asserts, “Curiosity can empower learners to engage in interesting and incidental learning that can positively impact students’ interactions and engagement with mathematics” (p. 29). Technology in the mathematics classroom is an essential vehicle that empowers students to make long term, timeless connections with mathematics.

REFERENCES


APPENDIX A

3-Act Math Tasks: https://whenmathhappens.com/3-act-math/
https://docs.google.com/spreadsheet/ccc?key=0AjiIQyKM9d7ZYdEhtR3BJMmdBWnM2YWxWYV
M1UWowTEE#gid=0
https://www.sfusdmath.org/3-act-tasks.html
https://gfletchy.com/3-act-lessons/
https://tapintoteenminds.com/3act-math/

Application Problems: https://www.yummymath.com/
http://www.achieve.org/ccss-cte-classroom-tasks
http://www.nctm.org/rsmtasks/

Desmos: https://www.desmos.com/

Desmos - Teacher: https://teacher.desmos.com/
https://sites.google.com/view/teaching-with-desmos/home

Edpuzzle: https://edpuzzle.com/discover

GeoGebra: https://www.geogebra.org/?lang=en

GeoGebra - Classroom Resources: https://www.geogebra.org/materials

Graphing Stories: https://tapintoteenminds.com/3act-math/graphing-stories/

Khan Academy: https://www.khanacademy.org/

Interactive Activities: https://www.mathwarehouse.com/
https://www.openmiddle.com/
https://www.turnersgraphoftheweek.com/

Problem-Based Learning: https://emergentmath.com/my-problem-based-curriculum-maps/

Screencasting: https://www.screencastify.com/
https://screenpal.com/
https://www.awesomescreenshot.com/
https://www.youtube.com/watch?v=JzpXvex_W7E

YouTube and Video Tutorials: https://www.youtube.com/
https://www.youtube.com/c/teachertubemath/playlists
https://www.youtube.com/c/videomathtutor/playlists
https://www.youtube.com/c/learnmathtutorials/playlists
https://mathtv.com/
APPENDIX B

Enhancing the Curriculum with Technology:

https://docs.google.com/presentation/d/19QX4zLgkOHJzDp7tYAcP8V0u1flf92NTYafBw3D4H9eo/edit#slide=id.g107bbb18966_0_73

Enhancing the Mathematics Curriculum with Technology:

https://docs.google.com/presentation/d/1iqxEs-h1JdWThsvh3ZNhai6FZHovPzEy8SAkY6yUlo/edit?usp=share_link

Transform your Teaching with Screencasting:

https://docs.google.com/presentation/d/1zf5wbV2ubWZRRhARQQwn6a_v5gmVt0rcyVBnROh4ydQ/edit#slide=id.g355e8606cc_0_129

Utilizing Technology to Differentiate the Mathematics Classroom:

https://docs.google.com/presentation/d/1bxmfScsqni41dBHqcw7Qmu5wsOcstVzirCFsj8XjU/edit?usp=sharing

APPENDIX C

Conic Sections Exploration - GeoGebra:

https://docs.google.com/document/d/1Fzf9XWVCzlpZJbf87UbCgSyG_ab_8HwFLBM4rovXj9M/edit?usp=sharing

Desmos Graphing Project:

https://docs.google.com/document/d/1_xbvjbJpc1CHQ3iDfxqiRpzC6nwROz_SiX6r2vLIj5s/edit?usp=sharing

Engage, Explore, Explain, Apply Template:

https://docs.google.com/document/d/1hT1Vd0n8bXT4O4BK99XkvhOhoAwgXrClGSHzC5OQ1I/edit

Application of Logs, pH, and the Demineralization of Teeth:

https://docs.google.com/document/d/1C5ZhPiB1QIkJKWhpM317c90UiyHaRoFuUXE69zQp_rU/edit?usp=share_link

Polar Graphs Exploration - Desmos:

https://docs.google.com/document/d/1cKkJ2DnYLu5YXBbYCAfBRvHgNM4_pQUSIEp4cFsaM8Q/edit

Trigonometry in the Real World:

https://docs.google.com/document/d/1iZnDUr3TBIXTamD6g0snqcNusz1ao4QtCHRk-ouVhs4/edit
Podcasting Readers Theatre: Engaging Work; Accelerated Results

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Using Readers Theatre as a strategy to engage elementary students in repeated reading to improve reading fluency has a decades-long track record of accelerated reading comprehension growth of up to one year’s progress in 10 weeks. Pairing this traditional strategy with podcasting is a powerful pairing that leverages the way voice is used to engage audiences. Podcasts offer additional benefits of reaching a wider audience than the classroom or school giving students a heightened sense of authenticity, which motivates the performers to work hard to “make it sound good.” Additionally, having a recorded artifact of the performance offers opportunity for self-evaluation and goal setting for the performers.

INTRODUCTION/CONTEXT

Imagine your classroom with small groups of students gathered around the computer or a tablet enthusiastically reading and rereading short, engaging scripts in which they each have a part to read. They record their performance to create a podcast to post on the class website considering the audiences who will later enjoy this performance. As they listen to their first attempts, they critique their performance and decide to re-record without prompting from the teacher and continue rereading and rerecording until they are satisfied with the product. These 21st century students experience the authenticity of creating a valued and public product: a podcast. Because the audience is real and potentially large, the quality of the work matters to them.

This process of reading and rereading a script is called Readers Theatre. In contrast to traditional theater that takes lots of orchestration of memorizing lines, creating costumes, and creating sets, Readers Theatre fits well into busy classrooms because the focus is on expressive reading to captivate the audience’s attention. There are no memorized lines, no costumes, and no sets (Martinez et al., 1999). This performance-based reading strategy supports improved reading fluency with the additional benefit of improved reading comprehension.

Three classroom-based studies of elementary students have shown an average of one-year’s progress in reading comprehension in 10 weeks when students engage daily in Readers Theatre (Griffin & Rasinski, 2004; Martinez et al, 1999; Vasinda & McLeod, 2011). One of the Readers Theatre studies used podcasts, creating a voice-only performance specifically matching the power of Readers Theater with additional benefits of a wider audience and self-evaluation throughout the process (Vasinda & McLeod, 2011). Imagine in your classroom podcasting Readers Theater, students listen to their initial recordings, they self-evaluate their performance, suggest revisions to the group, and say, “Let’s do it again. I need to say my part louder and sound more surprised in the beginning.”
RESEARCH REVIEW

Engaging in repeated reading is the most cited research-based practice for improving reading fluency which is the bridge between word identification and reading comprehension (Swain et al., 2013; Therrein, 2004). It is also identified as a strategy with a high effect size (.75). This means use of this strategy has documented effects of more than a year’s acceleration of progress (Fisher et al., 2016) in a shorter period of time. As mentioned above, students in second-, third-, and fifth-grade classrooms made an average of one year of progress in 10 weeks using Reader’s Theatre as a strategy to increase motivation for repeated reading. Daily script reading for 10-15 minutes supported increased reading fluency that led to accelerated gains in reading comprehension.

In the first classroom study, second graders performed for their classmates each Friday (Martinez et al., 1999). Loraine Griffin’s fifth grade students performed in the school library on Friday mornings for their classmates and parents who were invited to attend (Griffin & Rasinski, 2004). We broaden the listening audience through podcasts (Vasinda & McLeod, 2011). Second and third graders in six different classrooms across three schools, including two Title I campuses, created weekly podcasts of their Readers Theatre performances. These podcasts were posted to their classroom webpages where family and friends could access the performances at any time with the same average of a year’s worth of progress in 10 weeks’ time.

IMPLICATIONS

Podcasts continue to offer easy entry into authentic and valued digital literacy products as they require no expensive equipment, do not show images of students, and can be anonymous if the performers wish. There are many free and easy tool options, which also fits well into school budgets. Student performances can be posted to classroom webpages for easy family access.

Finding Scripts

Teacher preparation prior to beginning to implement podcasted Readers Theatre performances is choosing scripts with the strengths and needs of her students in mind. Teachers note that they easily find Readers Theatre scripts online and they also enjoy adapting favorite books into Readers Theatre scripts. Choosing scripts also provides opportunities for students to understand digital citizenship, Fair Use, and copyright issues. Appendix A includes free Readers Theatre script by authors who grant permission for their scripts to be performed as podcasts. It also describes ways that public domain works can be easily adapted as free-to-use scripts and titles continue to be added annually. and teachers and students often create their own scripts from adapting picture books, poems, short stories, or excerpts of larger texts that they love. Because Readers Theatre is a public performance, teachers need to abide by fair use and copyrights associated with creating podcasts, which is also explained further in Appendix A.

Creating Readers Theatre Groups

Give careful consideration to grouping your students and assigning parts. Readers who read below expected levels for their grade could be given an important part with a repeating line, such as Henny Penny’s, “The sky is falling! The sky is falling!” and work up to more varied parts as they gain confidence and competence. Grouping students of various reading levels provides opportunities for developing readers to hear fluent expressive reading with their peers who mentor them into more expressive reading.

The Weekly Routine

The investment of 10-15 minutes per day in this evidence-based literacy routine offers big returns of improvement in reading comprehension in a 10-week period. The weekly routine for teachers and students is designed to fit into a busy
classroom schedule working toward fluency and reading comprehension goals expected on state standards in an engaging way. Students have said On Mondays the teacher distributes the scripts and assigns parts. This is done with careful selection of the part for students who need extra support. On Tuesdays through Thursdays, each group reads and re-reads their parts getting smoother and more expressive as the practice. They work on their timing and flow. The teacher moves among the groups listening in, sometimes modeling particular phrases or parts, and coaching as needed for high-quality dramatic reading. Friday is recording day. Groups typically do a warm-up reading and then record their performance. The teacher uploads the audio files to her classroom webpage so that it is accessible to families and friends. Over the course of the 10 weeks, teachers remarked that their readers who struggled were excited to practice and wanted bigger parts as they progressed. The process is summarized in Table 1.

Table 1

Summary of weekly routine

<table>
<thead>
<tr>
<th>15-minutes</th>
<th>Teacher</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>Distribute scripts to small groups with assigned parts.</td>
<td>Students do their initial readings of their parts.</td>
</tr>
<tr>
<td>Tuesday - Thursday</td>
<td>Teacher supports students with listening in and often modeling expressive reading of certain sections.</td>
<td>Students practice mostly independently reading and rereading their scripts, encouraging each other, and setting goals for themselves.</td>
</tr>
<tr>
<td>Friday</td>
<td>Teachers upload podcasts to the class webpage.</td>
<td>Students record their scripts. They often re-record after a first listen.</td>
</tr>
</tbody>
</table>

Creating the Podcasts

There are many podcast software applications for computers and tablets. We have used Audacity on desktop computers and Wavepad on iPads. For this article, we feature Spotify for Podcasters (formerly Anchor FM), as it is currently hailed as one of the easiest to use podcast apps. Users can create their podcast episodes from a desktop, cell phone, or tablet. Students can create free accounts by using their Google account or other email address if they are at least 13 years old or have permission by a parent and/or guardian, or teachers can set up a class account. After logging in, on the right-hand side of the browser a “New Episode” button invites users to bring their ideas to life. (Figure 1)

Figure 1

Getting started to create a podcast episode

Next, users can create an episode by choosing to record or upload a supported file type (Figure 2).
Then the user drags the audio files to the “episode” and can choose to add music, transitions, or voice messages from followers (Figure 3).
After saving the episode, the screen asks for an episode title, a description, and a publication date (Figure 4).

**Figure 4**

*Naming and describing podcast episode*
Users also can save the file as a draft instead of publishing the episode to online audiences. This feature is uniquely beneficial for K–12 schools as some students may not prefer for their work to be online. The student can easily download the draft file from the website without ever publishing it to Spotify (Figure 5).

**Figure 5**

*Saving a podcast draft*

When using a cell phone or tablet, the user can open the Spotify for Podcasters application, select “Tools”, and then record in the same way as a desktop. There are two major differences that can serve different purposes between the application and desktop versions. The application has an “invite friends to join” option where the host can invite friends to join their podcast using a text message. The other difference is the desktop version allows recordings up to thirty minutes long using Google Chrome, five minutes long using Safari, and the application allows for recordings up to two hours long. We recommend podcasts of 5–10 minutes.

**Student Self-evaluation and Goal Setting**

Readers Theatre already offered accelerated progress in fluency and reading comprehension. Regardless of the audience, the reading comprehension gains were consistent across all three studies: one year’s comprehension growth in 10 weeks. The power of the podcasts provides a qualitatively different experience. First, students willingly practice their scripts over and over again anticipating an authentic and potentially wide audience. This understanding that “thousands and thousands of people might be ‘watching’” provides motivation to create a performance that others will enjoy. Teachers have remarked that they were surprised by the engagement of the students in this process. Second, because their performance is recorded, and there is a digital artifact that they can hear, students have opportunities to listen to their performance and critique their work. They notice when they have created the mood or tone they aimed for through their expressive reading. They also notice if they need to be louder next time or if they still need to work on being more animated and expressive. Students have noted that they “work hard to make it sound good”. In our experience, students
cheer each other on and encourage each other. They also prompt each other to come in on cue. Although we found the critique to come naturally, we have also created a self-evaluation rubric so that students and teachers evaluate progress and set new goals (Vasinda & McLeod, 2013) (Appendix A).

The purposeful and powerful pairing of Readers Theatre and podcasts amplified the effects of traditional Readers Theatre. The additional benefits include a wider audience and flexible access to performances so that families unable to attend daytime events at school were included as part of an online audience. The podcasts also provide a permanent record of their child’s performance within their small group so that they and their children can note improvement over time. Additionally, without prompting, students critique their podcasts, set personal goals for improving their reading performance within the week and for the next week. Lastly, they talked about their podcasts with visual language, such as “I couldn’t wait to show my podcast to my dad!” This made us wonder if perhaps they might be visualizing their reading more. Performance reading provided motivation to engage in repeated readings of the same text. By pairing an oral reading strategy with an oral performance technology, the defining features of each were leveraged for a powerful pairing that engages all readers while supporting developing readers.

REFERENCES


Vasinda, S., & McLeod, J. (2011). Extending Readers Theater: A powerful and purposeful match with podcasting. *The Reading Teacher, 64*(7), 486–497. [https://doi.org/10.1598/RT.64.7.2](https://doi.org/10.1598/RT.64.7.2)

## APPENDIX: STUDENT SELF-EVALUATION OF READERS THEATRE PODCAST RUBRIC

<table>
<thead>
<tr>
<th>Criterion</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expression</strong></td>
<td>I read my part with enthusiasm and good expression the whole way through. I changed my expression to match the mood or tone of my character and his/her situation all the way through.</td>
<td>I read my part with enthusiasm and good expression most of the time. I changed my expression to match the mood or tone of my character and his/her situation most of the time, but may have missed one or two changes.</td>
<td>I am beginning to use voice to make my part sound like natural talk in some places but not in others. I still have to stop and word-solve on some words.</td>
<td>My reading sounds like a robot and not like real talking. I still have to stop and word-solve on some words.</td>
</tr>
<tr>
<td><strong>Phrasing and smoothness</strong></td>
<td>I read my parts smoothly and come in on time. I know which words to read together as a phrase, or chunk. I read the ending punctuation to guide my expression. I fix up any mistakes quickly and keep going.</td>
<td>I read most of my parts smoothly and do not need a reminder to come in on time. Sometimes my reading is choppy, but most of my reading has the right expression.</td>
<td>It is hard to tell where my sentences end and begin. Sometimes I have to be reminded to ready my part at the right time. My reading sounds bumpy in some places. Sometimes I forget to change my voice for question marks and exclamation points.</td>
<td>I stop and start a lot. My reading sounds like a robot. It is difficult to tell where my sentences begin and end. My reading sounds like one word at a time. Sometimes I read the same part over and over again.</td>
</tr>
<tr>
<td><strong>Pacing</strong></td>
<td>My reading is just the right speed for my character and the situation.</td>
<td>My reading is just right most of the time, but sometimes I read a part too fast or too slow.</td>
<td>My reading sounds a little too slow or a little too fast. I need to try to match it to my character’s situation.</td>
<td></td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td>I change my voice volume to match the situation in my script the whole way through and my voice is always easy to hear.</td>
<td>My voice volume is just right throughout the text, but I don’t always remember to change the volume for different situations.</td>
<td>My voice sounds too quiet or too loud. It does not always match the situation in the script.</td>
<td>Sometimes I read so quietly that it cannot be heard. Most of my reading is too quiet.</td>
</tr>
</tbody>
</table>

Adapted from Vasinda & McLeod (2013)
During COVID-19, many schools shifted to online learning. Despite valiant efforts, there are indications that students struggled to maintain academic progress. Inevitably, many factors exacerbated online learning. In this chapter, I argue that the evasiveness of digital literacies may be a contributing factor. Research indicates that digital literacies are commonly obfuscated by digital skills, technology skills, technology literacy, media literacy, and other related concepts. Digital literacies is a nebulous concept that is difficult to disaggregate. However, without disaggregation, students may struggle with online learning. The purpose of this chapter is to describe a strategy for teachers to disaggregate digital literacies from related concepts, identify pertinent skills, and craft instruction with the ultimate goal of supporting preK–12 students’ online learning.

Keywords: digital literacies, preK–12 teachers, pedagogy, classroom instruction, technology, reading, writing, literacy

INTRODUCTION

In 2020, COVID-19 circumnavigated the globe. Many schools transitioned from in-person to online learning. Despite valiant efforts, research indicates that students lost ground and digital learning was inadequate (Chandasiri, 2020; U.S. Office of Civil Rights, 2021). While many factors exacerbated online learning, from a digital literacies perspective, lackluster learning was inevitable. Not because schools lacked technology, or teachers didn’t know how to use technology, or students didn’t know how to use technology. Rather, a contributing factor may be that we failed to teach students the digital equivalent of print literacies. We failed to teach students how to read and write digital texts. In other words, we failed to teach digital literacies.

This failure is no surprise. Digital literacies is a nebulous concept (Baker, 2022; Bali, 2016; Coiro, 2020). Scholars refer to new literacies, digital literacy (singular), online reading, and multiliteracies. K–16 classroom, media, and technology teachers explain that they simply overlook digital literacies, conflate them with related concepts, assume that students already know them, believe that the skills change as fast as ICTs and are quickly outdated and therefore irrelevant, or consider digital literacies to be the purveyance of other teachers (Baker, 2022). In addition, teachers’ professional organizations highlight varied digital standards (e.g., ALA Standards, ILA Standards, ISTE Standards).

The purpose of this chapter is to describe a strategy that preK–12 classroom, media, and technology teachers can use to clarify, disaggregate, and identify digital literacies that are pertinent to their students and persistent across ICTs. Teachers can thereby create targeted lessons with the ultimate goal of supporting students’ abilities to read and write digital texts. In other words, we failed to teach digital literacies.

Research Review

For centuries, to communicate with others beyond our immediate location, we learned to read and write alphabetic texts. Therefore, a primary mission for schools and teachers was to help students become proficient readers and writers of alphabetic texts. However, in recent decades, communication with others beyond our immediate location has become digital. And digital texts differ from non-digital texts (Patton Howell, 1990; Wheeler, 2019). In order to align literacy instruction with our digital world, we need to ascertain the basic characteristics of digital texts.
I, therefore, conducted a grounded theory analysis and found four characteristics of digital texts that have persisted and been consistent for over 25 years (Baker, 2020, 2021). Then, in an online graduate course for K–16 teachers, we used these characteristics to disaggregate digital literacies from related concepts and identify grade-specific skills. By the end of the course, teachers made such comments as,

I found the digital literacies [characteristics] and implications to be very meaningful. It really has helped me to focus on specific components of digital literacies. …Breaking down the specific [characteristics] of digital literacies has made the task of creating and planning lessons and tasks for students much more manageable. (Baker, 2022, n.p.)

Each characteristic has implications for readers and writers of digital texts. For example, one characteristic of digital texts is that they are persistently and consistently Public (see Table 1; e.g., Perrin & Atske, 2021; Roser et al., 2015; Roy, 2014). Social media posts can be shared with circles of friends or followers which, in turn, can be reshared. Hashtags, keywords, and hyperlinks can foster proliferation. Ultimately, digital texts have the potential to go viral within and across platforms. In other words, digital texts are public.

Table 1

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>Digital texts can be widely distributed</td>
</tr>
<tr>
<td>Semiotic</td>
<td>Using multimedia, digital texts are multimodal</td>
</tr>
<tr>
<td>Product-oriented</td>
<td>Authors compose digital products; readers make sense of digital products</td>
</tr>
<tr>
<td>Transitory</td>
<td>Digital texts can change; they can be in flux</td>
</tr>
</tbody>
</table>

Second, digital texts commonly incorporate alphabetic (e.g., typed words), pictorial (emojis, images), gestural (giphys, video), and auditory (narrations, music, lyrics) expressions. In one word, digital texts are consistently Semiotic (see Rowe, 1994; Serafini, 2014); they incorporate multiple modalities by leveraging multimedia.

Third, digital texts are commonly Product-oriented (see Baker, 2017; Roy, 2011; Salomon, 1993). For example, we compose slides, animations, videos, and posts. These digital products can be exchanged across time and space (Bakhtin, 1930/1981; Compton-Lily & Halverson, 2014; Leander & McKim, 2003).

Fourth, digital texts are ever-changing. They can be edited and altered for legitimate and nefarious purposes. AI can make actors appear as fictional characters, emulate the voice of political leaders, and create artwork and articles derived from the online collective. In other words, digital texts are Transitory (see Karlsson, 2012; Metz, 2013; Tolosana et al., 2020).

Implications

Because teachers can use these four characteristics of digital texts to gain conceptual footing with the otherwise slippery concept of digital literacies, I refer to them as Digital Literacies Footholds. In this section, I describe how teachers can use the Footholds to identify grade-specific digital literacies skills and design targeted instruction. The process guides teachers through a series of steps which involve brainstorming, deducing, unpacking, and transforming each Foothold into actionable lessons. Teachers may benefit from working through these steps with a small group of colleagues across several sessions.
Step 1: Become Familiar with the Digital Literacies Footholds

First, become familiar with each Foothold by reading or viewing *Wag the dog: A digital literacies narrative* (Baker, 2020, 2021). In this first step, get the big picture. In ensuing steps, I recommend that you return to each Foothold to dig deeper. Initially, just get the gist of each Foothold. Take notes by filling out Worksheet 1 (see Appendix).

Step 2: Brainstorm an Extensive List of ICTs

While reading or viewing *Wag the dog* (Baker, 2020, 2021), create a separate list of Information and Communication Technologies (ICTs). Make an extensive list. To make the list more manageable, group the ICTs. For instance, social media is an ICT group that includes TikTok, Instagram, and SnapChat. Collective Intelligence is an ICT group that includes Wikipedia, Kickstarter, property sharing, ride sharing, and online ratings (e.g., Airbnb/VRBO Uber/Lyft, Amazon, Rotten Tomatoes). Search engines refer to an ICT group that includes Google, Bing, and Duck Duck Go. While ChatGPT is a chatbot, you might include it with search engines because ChatGPT conducts online searches to engage in AI-produced conversations. Accurate grouping and labeling are not as important as generating a robust list of ICTs.

To unearth additional ICTs, ask your students what technologies they like to use to find information and communicate with family, friends, sports teams, and the like. Include online gaming (e.g., Fortnite and Minecraft), their favorite social media, and other ICTs they mention. Then, add the ICTs that your students may not use but are nonetheless popular. Pew Research Center conducts surveys to identify the social media platforms used by teens (see Vogels et al., 2022). These surveys can help you expand your growing list.

Keep a running list of ICTs. Update your list as you learn about additional ICTs. The purpose of the Digital Literacies Footholds is to identify the literacy skills needed to read (understand) and write (compose, communicate with) digital texts. The more robust your list of ICTs, the easier it is to identify digital literacies skills.

Step 3: Deduce ICT Characteristics for each Foothold

For the remaining steps, I use the Public Foothold as an example. The same series of steps are applicable to each Foothold. Specifically, return to your list of ICTs and highlight three to five ICTs that feature publicly available information and opportunities to communicate. This may be true of a majority of ICTs on your list. Pick a few that are important to your students. Using the previously mentioned categories, social media is inherently public. So, highlight all of the social media platforms on your ICT list. Collective intelligence relies on being public. Highlight Wikipedia, Kickstarter, property sharing apps, ride sharing apps, and online rating systems.

To find and sort the plethora of publicly available digital information, we use search engines. Highlight all of the search engines on your list.

Next, brainstorm and list the characteristics you can think of that make these ICTs public (see Table 2). For example, social media is public because anyone with online access can post. In addition, social media posts are discoverable by hashtags, hyperlinks, popularity sorting, keywords, likes, and subscriptions. Social media posts can go viral which makes them extremely public. Similarly, search engines sort the internet with proprietary algorithms that include keywords, links, content relevancy, popularity, paid ads, cookies, HTML code structures, and AI. Users are able to join the collective with keywords and location services. The collective is able to find users with cookies and location services. Conversely, consider how public information and communication ICTs can be restricted (Baker et al., 2015). Governments can shut down the internet (e.g., China, Russia, Iran), platform owners can change access requirements (e.g., Twitter), search engines can change algorithms (e.g., YouTube). In other words, while digital texts are commonly public, they can also be censored by governments, host companies, and algorithms. They are simultaneously democratized and monopolized (Greenwald, 2014).

Go to Worksheet 1 (see Appendix) and list the features that make ICTs public (see Table 3, ICT Characteristics). As you proceed with each Foothold, characteristics that make ICTs public may dawn on you. Continue to add and revise each Foothold as you proceed.
Table 2

ICTs that Feature Public Texts

<table>
<thead>
<tr>
<th>ICTs with Public Texts</th>
<th>ICT Characteristics, Public</th>
</tr>
</thead>
</table>
| Social Media           | • Anyone with online access can post  
| • Tik Tok              | • Discoverable by hashtags, hyperlinks, popularity sorting, keywords, likes, and subscriptions  
| • Instagram            | • Capable of going viral  
| • SnapChat             | • Use proprietary algorithms that include keywords, links, content relevancy, popularity, paid ads, cookies, and HTML code structures  
| Search Engines         | • Users join the collective with keywords and location services  
| • Google               | • Collective uses cookies and location services to find the user  
| • Bing                | • Censorship can occur: Governments can shut down the internet, platform owners can change access requirements, search engines can change algorithms  
| • Duck Duck Go         |   |
| • Chat GPT            |   |
| Collective Intelligence| • Protect safety  
| • Wikipedia            | • Maintain privacy  
| • Kickstarter          | • Address bullying  
| • Property Sharing: Airbnb, VRBO| • Be aware of censorship  
| • Ride Sharing: Uber, Lyft | • Search online  
| • Online Ratings: Amazon, Rotten Tomatoes, Airbnb, VRBO, Uber, Lyft | • Create searchable texts  
|                        | • Navigate the collective  
|                        | • Evaluate sources  
|                        | • Evaluate veracity  
|                        | • Evaluate search results  
|                        | • Consider the simultaneous democratization and monopolization of information  

Table 3

Public Foothold: Definitions, ICT Characteristics, and Implications

<table>
<thead>
<tr>
<th>Footholds</th>
<th>Definitions</th>
<th>ICT Characteristics</th>
<th>Implications of ICT Characteristics</th>
</tr>
</thead>
</table>
| Public    | Digital texts can be widely distributed | • Anyone with online access can post (communication can be democratized)  
|           |            | • Platforms are commercial entities (communication can be monopolized)  
|           |            | • Posts can go viral, across platforms, for legitimate and nefarious reasons  
|           |            | • Social media posts are discoverable by hashtags, hyperlinks, popularity sorting, keywords, likes, and subscriptions  
|           |            | • Users add to the collective by navigating contributor requirements (e.g., Wikipedia, online ratings)  
|           |            | • Cookies impact search results  
|           |            | • Algorithms impact search results (proprietary, AI)  
|           |            | • Protect safety  
|           |            | • Maintain privacy  
|           |            | • Address bullying  
|           |            | • Be aware of censorship  
|           |            | • Search online  
|           |            | • Create searchable texts  
|           |            | • Navigate the collective  
|           |            | • Evaluate sources  
|           |            | • Evaluate veracity  
|           |            | • Evaluate search results  
|           |            | • Consider the simultaneous democratization and monopolization of information  

Step 4: Unpack Implications for each Foothold

Now you are poised to identify implications of the publicness of ICTs. Revisit your list of characteristics that make ICTs public and brainstorm corresponding implications for users. In other words, for users to be proficient with social media, search engines, and collective intelligence, what do they need to know? What are the implications of emails and text messages going public (e.g., compromised privacy)? What do your students need to know to remain safe, deal with
bullying, and protect their identity? What skills do your students need to proficiently conduct online searches? How can they evaluate their search results? Do they know how to determine the validity of what they find? Do they understand cookies and how they impact online search results? Do they understand that each search engine has proprietary algorithms and generates different results? (see Yagci et al., 2022).

Generating a robust list of implications is the crux of transforming the Footholds from mere “characteristics of digital texts” to classroom instruction. Cogitate on the implications. Take a few days or a couple of weeks. Discuss the implications you generate with other teachers, friends, and family members. As you work with students, you will likely unpack additional implications. Go to Worksheet 1 (see Appendix) and list the implications for the publicness of digital texts (see Table 3, Implications of ICT Characteristics).

**Step 5: Transform Implications into Instructional Plans**

Finally, using Backward Design (Wiggins & McTighe, 2011), transform the implications of each Foothold into instructional plans. Start by converting your unpacked implications into learning goals. For example, the implication, “students need to remain safe when online,” can be converted into several goals:

- The students will (TSW) identify personal information that is currently public in their social media accounts,
- TSW classify their recent social media posts as safe or unsafe,
- TSW evaluate social media posts available in their stream and classify them as safe or unsafe for public distribution.

Take one of your goals and identify a series of activities that help your students accomplish the goal. For example, if your goal is for “students to evaluate social media posts available in their stream,” list the activities you want students to complete that gets them to the goal. Using your favorite lesson plan template, break the list of activities into a series of lessons. Now, you have a set of lessons designed to advance your students’ digital literacies learning.

**Step 6: Repeat for all Footholds**

Proceed with the same steps for each Foothold. Your list of implications and learning goals can become expansive. You might work with colleagues to formulate a scope and sequence of digital literacies skills your school can cover across and within grade levels.

Using the Digital Literacies Footholds, K–16 classroom, media, and technology teachers can gain clarity and the ability to target and teach digital literacies (Baker, 2022). Because the Footholds are inherently persistent across ICTs, they can be used to unearth digital literacies even as ICTs come and go. The more you use the Digital Literacies Footholds, the easier it becomes to recognize and teach digital literacies.

**REFERENCES**


Baker, E. A. (2022, December). *If reading is to offline learning as digital literacies are to online learning* [Paper presentation]. Literacy Research Association.


# APPENDIX

**Worksheet 1, Digital Literacies Footholds**

*Purpose*

Using the Digital Literacies Footholds, identify characteristics and implications for understanding (reading) and communicating (writing) with ICTs

*Directions*

Proceed through Steps 1-6. If needed, create 1+ pages for each Foothold.

<table>
<thead>
<tr>
<th>Footholds</th>
<th>Definitions</th>
<th>ICT Characteristics</th>
<th>Implications of ICT Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td></td>
<td></td>
<td>Users need to…</td>
</tr>
<tr>
<td>Semiotic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product-oriented</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transitory</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digital writing tools enable global citizens to create, communicate, evaluate, and collaborate in various contexts. As access to technology in the school and workplace continues to increase, elementary students must be prepared to utilize digital writing tools and platforms to complete various tasks. Additionally, elementary teachers must have digital writing knowledge to prepare their students. Our research focused on how teacher educators prepared elementary teachers to integrate digital writing into literacy instruction and the practices that elementary teachers can adopt to provide digital writing experiences to elementary students. Through our analysis of recent research in digital writing and by conducting a qualitative case study at a large southeastern university in the United States, we concluded that elementary teacher educators and elementary teachers should consider the following practices to integrate digital writing into instruction: model digital writing tools, discuss the affordances and constraints of various digital writing tools, and give students choice when completing digital writing tasks. These practices are supportive of elementary students’ development of literacy and technological knowledge. This chapter meet the goals of this book by providing evidence-based strategies that help educators facilitate the connection between modern digital writing research and classroom practice, and recommendations for integrating the practices into instruction.

INTRODUCTION

New technologies have impacted teaching and learning at the elementary, secondary, and post-secondary level by calling on educators to develop digital competence and promote digital competence in their students. Elementary teachers must go beyond lessons in digital citizenship and acceptable use of hardware at the start of a new academic year to include lessons that facilitate elementary students’ development of digital literacies. Specifically, to ensure elementary students can effectively communicate within digital mediums and demonstrate understanding of their learning through task completion, we must integrate digital writing into our curriculum. Digital writing is writing that integrates the use of computer technology and multimodal elements to convey ideas to various audiences (Freedman et al., 2016; Grabill & Hicks, 2005). In elementary students’ future, professional lives, they will operate in hybrid contexts that center both print and digital resources, tools, and platforms in their work (International Literacy Association, 2018). The 2020 What’s Hot in Literacy Report by the International Literacy Association revealed that 61% of educators considered teaching students to effectively use digital tools a top priority, while 34% of those respondents needed support in doing so. These findings suggest that as educators we must examine evidence-based practices in digital writing to deepen our knowledge and support elementary students in acquiring digital writing skills. In this chapter, we sought to support educators in integrating digital writing practices by providing strategies that enable elementary teachers and their students to use digital tools and platforms in pedagogical contexts.
RESEARCH REVIEW

Hicks suggested, “There is not a writer in our classrooms today who will not be producing something with a digital writing tool in her or his lifetime” (Hicks, 2013, as cited in Finley, 2013). Digital literacies, specifically digital writing, call on learners in a digital age to “consume, create, and curate” within and across multiple modalities (NCTE, 2019). When teachers provide elementary students with opportunities to integrate digital writing tools and work across modalities during instruction, positive effects on their writing, foundational reading skills, and vocabulary acquisition are observed (Gillis & Marshall, 2014; International Literacy Association, 2019). The use of digital writing tools and platforms may also support students and teachers in exploring and addressing social and cultural issues that emerge in their writing and class discussions (Brownell, 2021; Chisholm et al., 2019; Clarke, 2020).

We became curious about how developing elementary teachers were being prepared to integrate digital writing into literacy instruction. We conducted a case study at a large university in the Southeastern United States to investigate how elementary teacher educators described their digital writing knowledge and how they implemented this knowledge in literacy courses. Our investigation was guided by Koehler and Mishra’s (2008) Technological, Pedagogical, and Content Knowledge (TPACK) framework, which focuses on teachers’ knowledge in integrating and teaching with educational technology. By analyzing observations, interview transcriptions, and course resources, we concluded that teacher educators integrated digital writing practices that were responsive to elementary teachers’ abilities and interests. In the following section, we detailed some of these responsive practices that support development of digital writing knowledge and pedagogy in the elementary classroom.

IMPLICATIONS

Digital writing practices draw on students’ ability to demonstrate literacy learning while encouraging critical thinking, reflection, choice, and the need to see the possibilities for composing and presenting ideas to wide audiences that modern technology affords us. Educators must strive to help elementary students experience and understand what digital writing knowledge is and how to use it. We suggest that when educators integrate digital writing into instruction, students must be provided with tasks that reveal an opportunity to demonstrate their literacy knowledge and skills and deepen their learning. Elementary teacher educators and classroom teachers who integrate digital writing into their instruction are preparing their students to exchange ideas and collaborate in various modes with consideration for the best way to clearly communicate to their audience.

After investigating elementary teacher educators’ knowledge of and practices in digital writing, we concluded that elementary teacher educators’ practices were transferable to the K-5 classroom. In the following sections, we described three practices that we identified as applicable to the elementary classroom setting to support students’ development of digital writing knowledge and effective use of digital writing tools. These practices are supported by our interviews and observations of teacher educators during our case study research and by the work of other digital literacies and digital writing researchers.

Model the use of digital writing tools

Modeling is a strategy described within the Gradual Release of Responsibility Model (Fisher, 2008). Modeling refers to the time a teacher spends demonstrating a skill that he/she hopes students will eventually adopt into their own practices (Web et al., 2019). The benefit of modeling new strategies is that the teacher carries a large amount of cognitive responsibility to initially prepare students for eventual guided and independent practice. In our research, teacher educators discussed the importance of modeling the use of digital tools for elementary teachers. One of our research participants discussed how in the past she assumed that today’s digital natives are experts in technology. However, we must question developing elementary teachers’ and their students’ ability to effectively use technology to accomplish digital writing activities. To effectively model the use of digital writing tools, we must consider the purpose and intended outcomes of a task and what role digital writing may play in the completion of the task. Table 1 reflects the steps for modeling the use of digital writing tools as described and evidenced by participants in our research.
Table 1
Steps for modeling the use of digital writing tools and platforms

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> Explain the task and end goal.</td>
<td></td>
</tr>
<tr>
<td><strong>2.</strong> Make clear the reason for integrating a specific digital writing tool or platform into the task.</td>
<td></td>
</tr>
<tr>
<td><strong>3.</strong> Model accomplishing the task using the identified digital writing tool or platform while students follow along.</td>
<td></td>
</tr>
<tr>
<td>a. Consider thinking-aloud while modeling (i.e., “I clicked this feature because it will allow me to…”)</td>
<td></td>
</tr>
<tr>
<td><strong>4.</strong> After modeling, ask what questions or ideas students would like to discuss before trying out the tool on their own.</td>
<td></td>
</tr>
</tbody>
</table>

Modeling the use of digital writing tools leads to independence in using tools and selecting tools in the future (Baynum & Keyes, 2014; Martin, 2015). Developing elementary teachers and elementary students can successfully engage in opportunities for independent and collaborative practice with digital writing tools after seeing successful models by their teachers. Multiple studies addressing technological integration and the TPACK framework support the importance of modeling the use of technology. In their literature review of 88 empirical research studies measuring teachers’ knowledge, Wang, Schmidt-Crawford, and Jin (2018) concluded that modeling was effective in developing preservice teachers’ knowledge due to the frequency and accuracy of the modeling. Martin (2015) also found that modeling the use of technology increased preservice teachers’ confidence and competence in using digital tools. In their work with preservice teachers and elementary students focused on digital writing, Baynum and Keyes (2014) suggested that scaffolding and modeling both verbally and visually was an effective and necessary aspect of elementary students’ ability to digitally compose texts. Hancı-Azizoglu and Kavaklı (2021) also concluded that modeling was an effective strategy to promote creativity in language learners’ digital writing.

Discuss the affordances and constraints of digital writing tools

The ability to use a digital writing tool is only the tip of the metaphorical digital literacies iceberg. Digital literacies require critical thinking and reflective practices (Watulak & Kinzer, 2013). This idea is reflected in the practice of discussing affordances and constraints of various digital writing tools. During our observations of one of the teacher educators in our case study research, we observed the teacher educator guide elementary preservice teachers through realizing that Google Jamboard may not be the best platform for digital writing in the form of poetry due to the inability to insert line breaks, a unique and necessary structural element of poetry. We observed another participant help elementary teachers consider the benefits of using an iPad for creating Sketchnotes (McGregor, 2019) to reflect on literary experiences in comparison to drawing on paper. These discussions could only be had after the teacher educator provided modeling and opportunities for the teachers to apply their understanding of digital writing. However, the benefits were that the developing elementary teachers were given the opportunity to reconsider their selected digital writing mediums to accomplish their assigned tasks. Gillis and Marshall (2014) offered a framework for supporting teachers in reflecting on the integration of digital writing tools into instruction, which included analyzing what happened during instruction, noticing how students responded, and what may need to shift in future instruction. Therefore, we suggest the prompts in Figure 1 to help students recognize the affordances and constraints for digital writing tools and platforms.

We observed these questions discussed as a whole-class group in our case study research and suggest whole-class discussions because elementary students and elementary teachers can (a) reflect on the insight of one another, (b) offer methods for overcoming barriers posed by the constraints of digital writing tools, and/or (c) help their peers recognize additional affordances they have not identified. Through our research, we saw that the discussion of affordances and constraints of digital writing tools led to propositions for the use of other digital tools to accomplish the task, which facilitated developing elementary teachers’ ability to logically select digital writing tools and platforms that aligned to their learning objectives.
Prompts for discussing affordances and constraints of digital writing tools

<table>
<thead>
<tr>
<th>Affordances</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>What worked well when using this tool/platform?</td>
<td>What difficulties did you encounter while using the tool/platform?</td>
</tr>
<tr>
<td>What other tasks can we complete by using this tool/platform?</td>
<td>What feature(s) do you wish this tool had?</td>
</tr>
<tr>
<td>What aspects of this tool/platform are useful in contrast to others?</td>
<td>Why might another tool/platform work better?</td>
</tr>
</tbody>
</table>

Give students choice

As one’s knowledge of digital writing tools expands, he/she may become more competent in engaging in digital writing practices and using various tools (Martin, 2015). For learners to make logical choices about the best digital writing tool or platform to use for a specific task, they must have been witness to effective modeling by their teacher, engaged in digital writing using various tools and platforms, and reflected on the aspects of tools and platforms that can be leveraged in conjunction with those that constrain digital writing possibilities. As students and developing elementary teachers acquire more knowledge about how to use digital writing tools to accomplish literacy tasks, they may be ready to choose how they will demonstrate their literacy learning within a digital medium.

Participants in our case study highlighted the importance of providing choice to their developing elementary teachers’ use of digital writing tools and platforms due to their varying levels of digital competence. The teacher educators described that some elementary teachers demonstrate adequate literacy pedagogical and content knowledge but have difficulties integrating that knowledge with their technological competence. Thus, allowing choice and flexibility created a space for safe practice and comfortability for the developing preservice teachers, as opposed to requesting those with less digital competence meet the same expectations as others.

In elementary literacy instruction, students can determine how they would like to demonstrate their analysis and synthesis of information, such as integrating various sources of multimedia, if they are provided the opportunity to strategize in collaboration with others (Baynum & Keyes, 2014). We emphasize the importance of modeling and providing guided practice in an array of digital writing tools and platforms, such as those described in Table 2, to ensure learners have many choices to critically evaluate as they engage in digital writing. The table reflects some of the tools and platforms that were introduced by the elementary teacher educators in our study. These digital writing resources are also used in various K-5 settings that we support in our work as literacy leaders.
### Table 2

**Digital writing tools and platforms**

<table>
<thead>
<tr>
<th>Name of Tool/Platform</th>
<th>Website</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flip (previously Flipgrid)</td>
<td><a href="https://info.flip.com">https://info.flip.com</a></td>
<td>Users can create, respond to, and share videos.</td>
</tr>
<tr>
<td>Google Docs</td>
<td><a href="https://docs.google.com">https://docs.google.com</a></td>
<td>Google Docs is a digital word processing platform that allows users to simultaneously edit documents, make suggestions for edits to the document’s owner, and share the documents via link or publication to the web.</td>
</tr>
<tr>
<td>Google Slides</td>
<td><a href="https://docs.google.com/presentation/">https://docs.google.com/presentation/</a></td>
<td>This tool allows users to create slideshow presentations from preset or customized templates.</td>
</tr>
<tr>
<td>Jamboard</td>
<td><a href="https://jamboard.google.com/">https://jamboard.google.com/</a></td>
<td>This tool within the Google Drive platform allows users to collaborate and share writing through the inclusion textboxes, sticky notes, images, and shapes.</td>
</tr>
<tr>
<td>Kahoot</td>
<td><a href="https://kahoot.com/">https://kahoot.com/</a></td>
<td>Kahoot is a digital platform in which users can write, publish, and share quizzes that include sound, images, and audiovisual content.</td>
</tr>
<tr>
<td>Nearpod</td>
<td><a href="https://nearpod.com/">https://nearpod.com/</a></td>
<td>Nearpod allows users to create, share, and engage in interactive presentations that include audio, video, images, writing, and/or games.</td>
</tr>
<tr>
<td>Padlet</td>
<td><a href="https://padlet.com/">https://padlet.com/</a></td>
<td>This platform allows users to display content in multiple ways by creating or inserting text, audiovisual, and graphic elements.</td>
</tr>
</tbody>
</table>

We must remember that we, educators, must first enhance our own digital competence in digital writing prior to providing students with choices. It is imperative that we promote autonomous efforts while also being available to offer guidance in digital writing. When planning for instruction that allows elementary students choice in their digital writing, it will be helpful to consider the questions in Figure 2.

**Figure 2**

*Questions to ask when planning for student choice in digital writing*
These questions may help educators consider the possible “what-if scenarios” such as uncontrollable technological issues with a particular platform. When encountering difficulties, it may seem easiest to direct all learners to a platform that you find reliable and simple to access and use. However, we recommend planning ways to equip students to overcome the barriers they may potentially face when using a digital writing tool or platform of their choice.

Digital writing offers many possibilities to enhancing elementary literacy instruction. Integrating research-based instructional practices are imperative to successful digital writing integration in elementary literacy instruction and will ensure students are provided with many opportunities to effectively communicate their ideas, reflections, and learning with audiences within their classroom and beyond. To support elementary teachers in integrating digital writing into literacy instruction, we provided resources to learn more about digital writing (see Appendix A) and ideas for using digital writing tools and platforms in literacy instruction (see Appendix B).

REFERENCES


APPENDIX A

Learn More About Digital Writing

<table>
<thead>
<tr>
<th>Resource</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Teaching Writing in the Digital Age</em> by Joel Malley, National Writing Project <a href="https://www.youtube.com/watch?v=O9z71iNrlw">https://www.youtube.com/watch?v=O9z71iNrlw</a></td>
<td>Discussion and lessons learned from integrating digital writing into the classroom.</td>
</tr>
<tr>
<td><em>What is the TPACK Model?</em> by Common Sense Education <a href="https://www.youtube.com/watch?v=yMQiHJsePOM">https://www.youtube.com/watch?v=yMQiHJsePOM</a></td>
<td>Description of the TPACK Model teacher recommendations for innovative instruction.</td>
</tr>
</tbody>
</table>

APPENDIX B

Ideas For Integrating Digital Writing Into Your Literacy Instruction

<table>
<thead>
<tr>
<th>Tool/Platform</th>
<th>Sample Task</th>
<th>Associated Literacy Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Draw</td>
<td>Design a digital poster to demonstrate how an author developed a theme in a literary text.</td>
<td>● Determine the theme of a literary text. ● Analyze the development of a theme.</td>
</tr>
<tr>
<td>Padlet</td>
<td>Use photographs, audio, and text to compare the experiences of characters in two versions of the same story.</td>
<td>● Describe literary elements such as characters and plot. ● Determine significant details in a story. ● Compare and contrast character experiences.</td>
</tr>
<tr>
<td>Mentimeter</td>
<td>Select one word that describes the main character’s motivation to add to the class Word Cloud.</td>
<td>● Analyze character motivations. ● Paraphrase information in a literary text.</td>
</tr>
<tr>
<td>Google Jamboard</td>
<td>Use the sticky note feature to identify the topic, central idea, and relevant details in an informational text.</td>
<td>● Analyze the central idea of a text. ● Select details that support one’s understanding of a text.</td>
</tr>
<tr>
<td>Flip</td>
<td>Create a video to present a response to the argumentative writing prompt including evidence from at least two texts.</td>
<td>● Make claims about a topic or idea. ● Support claims using reason and evidence from a text.</td>
</tr>
</tbody>
</table>
This chapter discusses the challenges of “theorizing idiomatics practice” and “practicing idiomatics theory” in diverse English learning environments. Research findings are often communicated in academic jargon, making them difficult to understand for English educators and language practitioners. The chapter advocates for accessible research and provides evidence-based proposals for teaching, learning, and assessing idiomatics—the study of idiomatic and figurative language beyond literal interpretation. It emphasizes the need to teach idiomatics systematically and productively across language proficiency levels and schooling stages, incorporating it across the digital curriculum. Just as not every nonliteral expression is a “nail” and not every digital tool is a “hammer,” English teachers must recognize the effectiveness of technology depends on how skillfully it is used. Striking a balance between exploring and creating idiomatics content in real-life settings is key to enhancing engagement, interactivity, and collaboration among English learners. This learning principle applies to all multimedia materials featuring authentic idiomatic and figurative language. So contextualized, the evidence-based proposals outlined in the chapter serve as a roadmap for enhancing idiomatics instruction in the digital era, bridging the gap between theory and practice and providing practical insights for creative and interactive digital practices in diverse educational settings here and abroad, and especially at the secondary level.

INTRODUCTION

The complexity of “theorizing idiomatics practice” and “practicing idiomatics theory” are challenging regardless of the learning environment or glocal (global-local) context. It is difficult to communicate research findings into digital practices that English teachers can trust and understand, often because we present them in academic jargon and style that is hard to decipher. Expecting secondary educators and English language practitioners to read and appreciate our research and distill the most salient insights is, to put it bluntly, unrealistic. We must do better to make our research more accessible and understandable. Excuses are no longer acceptable (McGann et al., 2020; Rycroft-Smith, 2022). In this chapter, I aim to provide an easy-to-read guide on the integration of educational technology into teaching and learning English idiomatics for secondary educators and English language practitioners alike. Idiomatics refers to the scientific study of idiomatic and figurative language, where idiomatic language is the natural way of expressing oneself in a language, and figurative language is the creative use of language to suggest meaning beyond its literal interpretation (Liontas, 2021, p. 32). It is imperative to teach idiomatics systematically and productively, regardless of language proficiency or level of schooling, from elementary school to graduate school and beyond. We need to embrace the whole spectrum of language, warts and all, without hesitation and incorporate it across the curriculum from the very beginning.

RESEARCH REVIEW

Since the 1970s, numerous hypotheses and models have been proposed to describe how language users access, process, and interpret both literal and non-literal language. These include the idiom list hypothesis, the lexical representation hypothesis, the figurative first hypothesis, the holistic hypothesis, the idiom decomposition model, the configuration model, the hybrid model, and the dual route model. These hypotheses are frequently cited in relation to first language (L1) speakers, while the graded salience hypothesis, the idiom diffusion model, the dual idiom representation model, and the literal salience model are prominent proposals for second language (L2) speakers. (See Appendix A for specific references associated with this work and the work presented in the “Implications” section.)
Despite decades of research and a wealth of empirical evidence, no single model or hypothesis has been able to provide definitive answers for the processing, retrieval, and understanding of idioms by both L1 and L2 learners, or for the learning and acquisition of idiomatics. English teachers and L2 language practitioners alike are often left to rely on their own instincts, beliefs, and values to find pedagogical or technological solutions. In this chapter, I present several evidence-based proposals that aim to translate research into actionable outcomes for L1/L2 English teaching, learning, and assessing idiomatics. These proposals focus on leveraging digital tools with pedagogical constructs to enhance accessibility and engagement in teaching and learning idiomatics. Additionally, I provide supporting evidence and resources to facilitate the application of these proposals in the classroom. Together, these proposals offer a roadmap for exploring and discovering new strategies for effective English idiomatics instruction in the modern digital age.

Implications

To promote meaningful L1/L2 English language learning experiences and encourage the creation and sharing of user-generated content involving idiomatics, secondary educators and English language practitioners can utilize a range of interactive Web 2.0 technologies and related resources. These may include social networking service platforms, content management systems, web conferencing, communication and collaboration tools, and document-authoring and assessment applications. However, it is essential for educators and practitioners to use these tools purposefully and intentionally, aligning their use with the intended function of each digital technology. As Maslow (1966) aptly stated, “If the only tool you have is a hammer, it is tempting to treat everything as if it were a nail.” It is thus crucial to recognize that not every expression or figure of speech is a “nail,” and not every tool is a “hammer.”

Since time immemorial, the effectiveness of a tool depends on the skillfulness of the hands that wield it. In English language learning, striking the perfect balance between exploring-discovering idiomatics content and creating-sharing idiomatics knowledge in real-life settings is key to enhancing engagement, interactivity, and collaboration among L1/L2 learners. Technology and tasks/projects used in English idiomatics instruction should be carefully adapted across the curriculum, considering local and state standards, curricular goals and objectives, and student needs and interests. This learning principle applies to all multisensory/multimodal print and media materials that feature authentic idiomatic-figurative language, such as texts, songs, movies, literature, art, and music. (For a comprehensive review of principles and practices of understanding idiomacity, refer to Liontas, 2018b, pp. 7–10). Proposals for idiomatics instruction should also consider students’ intellectual maturity and linguistic ability, including their proficiency in using digital technologies. Here are 11 evidence-based proposals, each indicating the intended function and technology/resource to achieve the desired learning outcome.

First, suggest that students conduct online etymological research on idiomatic or figurative expressions. Give students a list of no more than ten idiomatic expressions you want them to research (see “Appendix B” for a list of 259 English binomials/trinomials, similes, idioms, proverbs, clichés, phrases, and sayings). Students could be assigned into groups of four to five members and each group could be given a different list of idiomatic-figurative expressions if so desired. Next, instruct students on how to undertake such research using reputable sources like https://www.etymonline.com/word/idiom. Afterward, instruct students/groups to record their findings utilizing Google Docs (https://www.google.com/docs/about/), a web-based word processor with built-in editing and styling features, integrated with Google Drive (https://www.google.com/drive/). As students/groups begin to peruse their etymological findings, they are bound to find new ways to better express their research. Doing so allows for real-time collaboration on the same document, with multiple users editing simultaneously. Different fonts can be used as needed. Once the final idiomatics output is complete, it can then be presented and shared using Google Slides (https://www.google.com/slides/about/), or other presentation tools like PowerPoint or Prezi for visually engaging presentations with multimedia elements (see “Idiom Activities” in Google Drive for a sample of idioms, images, and activities; https://drive.google.com/drive/folders/1YRKr-XF1I3zwcmq4kJZfUxPsQWY5k_e?usp=share_link).

To encourage the exchange of ideas and information on idiomatics, students can leverage a variety of communication tools. Synchronous voice chat application tools like Apple’s iMessage (www.support.apple.com/explore/messages) allow students to engage in real-time discussions with their peers about culturally appropriate socio-pragmatic expressions and figures of speech that convey mental states of awareness or emotions. They can easily send text, pictures, videos, sound, location, bubble and screen effects, emoji tapbacks and full-on emojification, digital touch, and handwriting over Wi-Fi or cellular-data networks, enhancing personal and social meaning-making processes involving idiomatics.
Desks, laptops, smartphones, and mobile devices provide a multitude of chat programs such as Facebook Messenger, FaceTime, Google Voice, Line, Microsoft Teams, Signal, Skype, Telegram, Viber, WeChat, WhatsApp, and Zoom, which allow for instant multimedia sharing (e.g., images, videos, audio) via text messaging or Short Message Service (SMS) across traditional cellular networks. Additionally, there are numerous social networking service (SNS) platforms/social media (SM) available to students for establishing online social connections or building relationships, such as Facebook, WhatsApp, Twitter, Instagram, Pinterest, Snapchat, and Reddit. Students can also explore video-sharing sites such as TikTok, YouTube, Vimeo, or Twitch. For guidance on effectively leveraging SNS and SM platforms showcasing idiomatic-figurative language, refer to Liontas (2018a, pp. 47–48) and Liontas (2018b), respectively.

To imitate and spread idiomatic-figurative ideas through memes, students can create their own memes using popular meme generators like Filmora (https://filmora.wondershare.com), Canva (https://www.canva.com/create/memes/), Kapwing (https://www.kapwing.com/meme-templates), or other similar tools. These tools allow students to create captioned pictures, videos, interactive, or promotional memes in just a few simple steps. Students can also use their own pictures to depict idioms and figures of speech. They can find meme maker online options by visiting websites like Top 12 Best Meme Makers Online for FREE, https://filmora.wondershare.com/meme/best-free-meme-maker-online.html (For a sample of 10 amusing memes created using Kapwing, see https://drive.google.com/drive/folders/1YRKr-XF13zwcmq4kJFJuXPsovY5k_c?usp=share_link)

To create an immersive and interactive meeting experience for online collaboration, virtual classrooms, and large webinars on idiomatics, consider using Adobe Connect (www.adobe.com), a platform with powerful multi-user web conferencing and file/screen sharing capabilities. Adobe Connect offers a 90-day free trial for up to 25 participants, after which the solution is available across 3 different packages. Similarly, to engage students in real-time collaboration, use Bit.ai (https://bit.ai/), a cloud-based document collaboration platform for teams regardless of where they are located. Bit.ai offers a free plan, a pro plan, and a business plan. To post and share notes containing links, audio, videos, images, and document files related to idiomatic-figurative language, use Padlet (https://padlet.com/), an online bulletin board with various layout options promoting brainstorming, collaboration, and reflection. Additionally, to create idiomatics “grids” and post questions for students to answer with short video responses displayed as tiles on the grid, use FlipGrid (https://info.flip.com/), a social learning tool.

To elevate interaction and engagement among secondary students, Wimba Create (www.wimba.com/index.php) is a valuable tool to consider. This software allows users to record oral messages and create voice discussion boards. Incorporating voice messages into online discussion boards focused on idiomatics can add a dynamic and immersive element, allowing L1/L2 students to express themselves verbally and practice their skills in using idiomatic-figurative language. These activities can be completed individually or collaboratively, fostering a truly collaborative learning environment. For more information, you can download the 142-page reference guide as a PDF at https://wiki.umontreal.ca/download/attachments/76220786/wimba_reference.pdf?version=1&modificationDate=1275056413000&kapi=v2.

To enable students to create and share their own language-based content on idiomatic-figurative topics through audio or video podcasts (vodcasts), one effective tool to consider is Audacity (www.audacityteam.org), a free, open-source, cross-platform audio software that allows for multi-track recording and editing. Audacity empowers students to record and edit their audio or video content, adding layers of creativity and personalization to their idiomatics vodcasts. They can then upload their vodcasts to hosting sites to share with peers, showcasing their language skills and promoting collaborative learning. Through this engaging, multimedia-rich process, L1/L2 students can express their ideas and perspectives in a unique and creative way, while also developing their technological and media literacy skills. Both podcasts and vodcasts offer a visually engaging spectrogram view of tracks that can be edited based on feedback from peers or teachers, promoting understanding of formal aspects such as prosodic features, stress, rate, pronunciation, and intonation. Additionally, as students reflect on their English language output and receive feedback from peers or teachers, they develop metacognitive skills such as self-assessment, monitoring, and self-regulation of their idiomatic-figurative language use. Developing skills in planning, attending to, and self-evaluating nuanced language output through constructive feedback loops promotes deeper learning and proficiency in idiomatics.

To encourage cooperative/collaborative writing exercises focused on idiomatics, L1/L2 students can employ wikis, that is, web-based platforms that facilitate collaborative editing and content structuring through simplified markup language. They can generate discussion or informational blogs on a variety of topics related to idiomatic-figurative language, sociopragmatic functions, and linguacultural aspects using free blog sites like Blogger, Penzu, Squarespace, Tumblr, and Weebly. Students can upload different types of media, including text, digital images, animations, videos, and links, and engage with others through comments on blog entries involving idiomatics. Vlogs, music blogs, photoblogs,
podcasts, and vodcasts provide real-life settings for practicing linguacultural content. Teachers can also assign idiomatics tasks or projects using publishing tools to target specific English language modalities or achieve curricular/course goals. Specifically, to help students create digital portfolios showcasing their L1/L2 learning journey with multimedia content related to idiomatic-figurative language, platforms such as *WordPress* ([https://wordpress.com/])—a free and open-source content management system, and *Google Sites* ([https://sites.google.com/new])—a structured wiki- and webpage-creation tool offered by Google, can be utilized. To learn how to set up a wiki and use it effectively, visit [https://www.mind-tools.com/ahifggz/how-to-create-a-wiki](https://www.mind-tools.com/ahifggz/how-to-create-a-wiki). Both these tools allow for creative and interactive curation and publication of idiomatics learning experiences. Moreover, students can enhance their multimedia content by manually adding closed captions to auditory input or utilizing automated closed captioning services like *YouTube*. This promotes inclusive and differentiated instruction for students with hearing disabilities and supports L1/L2 learners with listening skills. These digital tools also enable students to receive feedback from peers and English teachers, gain wider audience exposure, and develop essential digital literacy skills. (*For The Ultimate Guide to Add Closed Captions & Subtitles to YouTube Videos, visit [https://www.rev.com/blog/resources/how-to-add-closed-captions-subtitles-to-youtube-videos](https://www.rev.com/blog/resources/how-to-add-closed-captions-subtitles-to-youtube-videos)*)

To seamlessly integrate the assessment of English idiomatic-figurative expressions into the instructional process, quiz tools such as *Google Forms*, *Microsoft Forms*, and LMS-based quizzes can be utilized. These versatile tools provide various question types, including multiple-choice and open-ended questions, enabling instructors to offer personalized feedback based on students’ responses. More specifically, to enhance the effectiveness of formative assessments, gamified assessments offering automated and teacher/peer feedback can be incorporated into idiomatics instruction. *Kahoot!* ([https://kahoot.com/]), a game-based learning platform, aids English teachers to create multimedia quizzes, surveys, and games for students, while *Quizizz* ([https://quizizz.com/]) enables the creation of quizzes, polls, open-ended questions, and 3D objects with built-in metrics that measure classroom participation and concept clarity. These tools make the assessment process engaging, enjoyable, and interactive, facilitating real-time and asynchronous quiz-like competitions among L1/L2 learners. *Quizalize* ([https://www.quizalize.com/]) is another gamified formative assessment application that collects real-time data on student progress and allows for personalized idiomatics learning through classroom quizzes, exams, or homework assignments with team progress or live results. *Quizlet* ([https://quizlet.com/]) is an online flashcard maker tool that helps students create their own idiomatics flashcard sets for studying. Additionally, *BookWidgets* ([https://www.book-widgets.com/]) is a productivity app that can be used to create digital idiomatics exercises and tests that are automatically graded with feedback. The data collected from these quizzes offer valuable insights into students’ understanding of idiomatic-figurative expressions, helping instructors identify areas that may require additional instruction or interventions. Through data analysis, educators can monitor students’ progress in idiomatics knowledge and discern their individual idiomatic-figurative language development path. In all, these quiz tools enable systematic and efficient assessment of English idiomatics, enhancing language instruction effectiveness and promoting personalized learning experiences for all students (see also “KAHOOT Idiom Activities” in [https://drive.google.com/drive/folders/1YRKr-XFI3zwcmq4kJZUxPsQWY5k_c?usp=share_link](https://drive.google.com/drive/folders/1YRKr-XFI3zwcmq4kJZUxPsQWY5k_c?usp=share_link)).

To create entertaining videos showcasing their understanding of idiomatic-figurative language, students can use the user-friendly platform *Animoto* ([https://www.animoto.com/]). With just four simple steps of selecting a template, uploading video clips and photos, arranging and dropping media, and customizing projects, *Animoto* allows users to easily produce and share videos on idiomatics. It offers a creative medium for students to demonstrate their improving knowledge of idiomatics while having fun and producing digital works that can be treasured for years to come. Best of all, *Animoto* is free to use, making it accessible to all L1/L2 learners. For additional options, students can also explore *WeVideo* ([https://www.wevideo.com/]) for creating and sharing idiomatics videos and animations on social media, *InShot* ([https://inshot.com](https://inshot.com)) for powerful photo and video editing on mobile devices, and *iMovie* ([https://www.apple.com/imovie/]) for free video editing on Mac, iPhone, and iPad with a range of effects and tools like color correction and image stabilization. *A Beginner’s Guide to Getting Started in iMovie* can be found at [https://blog.storyblocks.com/video-tutorials/getting-started-imovie](https://blog.storyblocks.com/video-tutorials/getting-started-imovie) (also see “Idiom Videos Made Simple—Animoto, iMovie, InShot” in [https://drive.google.com/drive/folders/1YRKr-XFI3zwcmq4kJZUxPsQWY5k_c?usp=share_link](https://drive.google.com/drive/folders/1YRKr-XFI3zwcmq4kJZUxPsQWY5k_c?usp=share_link)).

To demonstrate their purposeful production of idiomatic-figurative language in an interactive format, students can leverage *Book Creator* ([https://bookcreator.com/]). This versatile tool enables users to create and publish digital books, including comic strips, with customizable pages and options to resize and reposition images, modify text attributes, and add or modify background colors as needed. This platform offers a great opportunity for students to exhibit their creativity and comprehension of idiomatics in a visually appealing manner.
REFERENCES


APPENDIX A

Literature Reading List

The most often cited hypotheses/models suggested for first language speakers include the…

Idiom list (literal first) hypothesis


Lexical representation (simultaneous processing) hypothesis


Figurative first hypothesis (or direct access model)


Holistic hypothesis


Idiom decomposition model


Configuration model

Hybrid model or Constraint-based model


Dual route model

Van Lancker Sidtis, D. (2004). When novel sentences spoken or heard for the first time in the history of the universe are not enough: Toward a dual-process model of language. *International Journal of Language & Communication Disorders, 39*(1), 1–44. [https://doi.org/10.1080/13682820310001601080](https://doi.org/10.1080/13682820310001601080)


Notable proposals for second language speakers include the…

Graded salience hypothesis


Idiom diffusion model


**Dual idiom representation model**


**Literal salience model**


**Reading List Concerning Phrasal verbs and phrasal expressions**


**Vivid phrasal idioms, figurative idioms, and idioms**


**Collocations, metaphors, and metonymies**


**Formulaic language and formulaic sequences**


Proverbs, idiomatic language, and idiomatic/multiword expressions and phrases


Figures of speech and figurative language


Artificial intelligence knowledge systems and idiom learning


User-generated idiomatics content and AR-infused worlds


Digital stories and language teacher identity negotiations


Reading List Concerning Idiomatics Implications


## APPENDIX B

List of Binomials, Trinomials, Similes, Idioms, Proverbs, Clichés, Phrases and Sayings

### Binomials and Trinomials (n = 53)

<table>
<thead>
<tr>
<th>Binomial/Trinomial</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>backwards and forwards</td>
<td>judge, jury, and executioner</td>
</tr>
<tr>
<td>blood, sweat, and tears</td>
<td>kiss and tell</td>
</tr>
<tr>
<td>bread and butter</td>
<td>law and order</td>
</tr>
<tr>
<td>by and large</td>
<td>live and learn</td>
</tr>
<tr>
<td>cool, calm, and collected</td>
<td>lock and key</td>
</tr>
<tr>
<td>crash and burn</td>
<td>lock, stock, and barrel</td>
</tr>
<tr>
<td>do or die</td>
<td>loud and clear</td>
</tr>
<tr>
<td>eye to eye</td>
<td>make or break</td>
</tr>
<tr>
<td>far and wide</td>
<td>meat and potatoes</td>
</tr>
<tr>
<td>fight or flight</td>
<td>meet and greet</td>
</tr>
<tr>
<td>fish and chips</td>
<td>mind, body, and soul</td>
</tr>
<tr>
<td>grin and bear it</td>
<td>no ifs, ands, or buts</td>
</tr>
<tr>
<td>hard and fast</td>
<td>nook and cranny</td>
</tr>
<tr>
<td>here, there, and everywhere</td>
<td>one way or another</td>
</tr>
<tr>
<td>hit or miss</td>
<td>ready, willing, and able</td>
</tr>
<tr>
<td>hook, line, and sinker</td>
<td>red, white, and blue</td>
</tr>
<tr>
<td>hop, skip, and jump</td>
<td>rough and tumble</td>
</tr>
<tr>
<td>hot and cold</td>
<td>safe and sound</td>
</tr>
<tr>
<td>said and done</td>
<td>sick and tired</td>
</tr>
<tr>
<td>sick and tired</td>
<td>skin and bones</td>
</tr>
<tr>
<td>skin and bones</td>
<td>spick and span</td>
</tr>
<tr>
<td>stars and stripes</td>
<td>straight and narrow</td>
</tr>
<tr>
<td>the good, the bad, and the ugly</td>
<td>the whole kit and caboodle</td>
</tr>
<tr>
<td>thick and thin</td>
<td>this, that, and the other</td>
</tr>
<tr>
<td>time and tide</td>
<td>tit for tat</td>
</tr>
<tr>
<td>Tom, Dick, and Harry</td>
<td>warm and fuzzy</td>
</tr>
<tr>
<td>touch and go</td>
<td>way, shape, or form</td>
</tr>
<tr>
<td>wine and dine</td>
<td></td>
</tr>
</tbody>
</table>

### Similes (n = 33)

<table>
<thead>
<tr>
<th>Simile</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black as coal</td>
<td>Dry as a bone</td>
</tr>
<tr>
<td>Blind as a bat</td>
<td>Flat as pancake</td>
</tr>
<tr>
<td>Bold as brass</td>
<td>Free as a bird</td>
</tr>
<tr>
<td>Busy as a beaver</td>
<td>Gentle as a lamb</td>
</tr>
<tr>
<td>Clean as a whistle</td>
<td>Happy as a clam</td>
</tr>
<tr>
<td>Clear as crystal</td>
<td>Hard as a rock</td>
</tr>
<tr>
<td>Cold as ice</td>
<td>Heavy as lead</td>
</tr>
<tr>
<td>Common as dirt</td>
<td>Light as a feather</td>
</tr>
<tr>
<td>Cool as a cucumber</td>
<td>Nutty as a fruitcake</td>
</tr>
<tr>
<td>Cute as button</td>
<td>Old as time</td>
</tr>
<tr>
<td>Dead as a doormail</td>
<td>Playful as a kitten</td>
</tr>
<tr>
<td>Pretty as a picture</td>
<td>Quiet as a mouse</td>
</tr>
<tr>
<td>Rough as sandpaper</td>
<td>Sharp as a tack</td>
</tr>
<tr>
<td>Sharp as a tack</td>
<td>Slow as a snail</td>
</tr>
<tr>
<td>Soft as a pillow</td>
<td>Sweet as honey</td>
</tr>
<tr>
<td>Sweet as honey</td>
<td>Thin as a rail</td>
</tr>
<tr>
<td>Tough as nails</td>
<td>Warm as toast</td>
</tr>
<tr>
<td>White as a ghost</td>
<td></td>
</tr>
</tbody>
</table>
### Idioms (n = 73)

<table>
<thead>
<tr>
<th>Idiom</th>
<th>Idiom</th>
</tr>
</thead>
<tbody>
<tr>
<td>add fuel to the fire</td>
<td>keep your nose to the grindstone</td>
</tr>
<tr>
<td>be at the end of one’s rope</td>
<td>kill two birds with one stone</td>
</tr>
<tr>
<td>be caught between a rock and a hard place</td>
<td>leave someone high and dry</td>
</tr>
<tr>
<td>be green with envy</td>
<td>let the cat out of the bag</td>
</tr>
<tr>
<td>be on the ball</td>
<td>look for a needle in a haystack</td>
</tr>
<tr>
<td>be wet behind one’s ears</td>
<td>lose one’s shirt</td>
</tr>
<tr>
<td>beat around the bush</td>
<td>make a mountain out of a molehill</td>
</tr>
<tr>
<td>behind the eight ball</td>
<td>make a splash</td>
</tr>
<tr>
<td>bite off more than they can chew</td>
<td>not have a leg to stand on</td>
</tr>
<tr>
<td>bite the bullet</td>
<td>people who live in glass houses should not throw stones</td>
</tr>
<tr>
<td>bite the dust</td>
<td>pull someone’s leg</td>
</tr>
<tr>
<td>build castles in the air</td>
<td>pull the rug out from under someone’s feet</td>
</tr>
<tr>
<td>burn the midnight oil</td>
<td>put all one’s eggs in one basket</td>
</tr>
<tr>
<td>bury the hatchet</td>
<td>put one’s money where one’s mouth is</td>
</tr>
<tr>
<td>cost an arm and a leg</td>
<td>put the cart before the horse</td>
</tr>
<tr>
<td>drop the ball</td>
<td>raise some eyebrows</td>
</tr>
<tr>
<td>find a hair in one’s soup</td>
<td>read between the lines</td>
</tr>
<tr>
<td>follow in someone’s footsteps</td>
<td>see eye to eye</td>
</tr>
<tr>
<td>get caught red-handed</td>
<td>sit on pins and needles</td>
</tr>
<tr>
<td>get the ball rolling</td>
<td>smell a rat</td>
</tr>
<tr>
<td>get up on the wrong side of the bed</td>
<td>spill the beans</td>
</tr>
<tr>
<td>give him an inch, and he’ll take a mile</td>
<td>split hairs</td>
</tr>
<tr>
<td>go down the drain</td>
<td>stick out one’s neck</td>
</tr>
<tr>
<td>go through something with a fine-toothed comb</td>
<td>stop beating around the bush</td>
</tr>
<tr>
<td>hang by a thread</td>
<td>take a page out of someone else’s book</td>
</tr>
<tr>
<td>have a screw loose/missing</td>
<td>take the bull by the horns</td>
</tr>
<tr>
<td>have eyes bigger than one’s stomach</td>
<td>talk about someone behind his or her back</td>
</tr>
<tr>
<td>have eyes in the back of one’s head</td>
<td>the straw that broke the camel’s back</td>
</tr>
<tr>
<td>have someone on a ball and chain</td>
<td>throw fuel on the fire</td>
</tr>
<tr>
<td>have someone wrapped around one’s little finger</td>
<td>throw in the towel</td>
</tr>
<tr>
<td>have something up one’s sleeve</td>
<td>throw money out the window</td>
</tr>
<tr>
<td>have the world by the tail</td>
<td>throw the book at someone</td>
</tr>
<tr>
<td>hit the ceiling</td>
<td>tread on thin ice</td>
</tr>
<tr>
<td>hit the nail on the head</td>
<td>turn a blind eye</td>
</tr>
<tr>
<td>keep one eye on</td>
<td>when pigs fly</td>
</tr>
<tr>
<td>keep your ear to the ground</td>
<td>you scratch my back, I scratch yours</td>
</tr>
<tr>
<td>keep your eye on the ball</td>
<td></td>
</tr>
</tbody>
</table>

*Note: The list includes a variety of idioms commonly used in English language.*
Proverbs (n = 75)

A bird in the hand is worth two in the bush.
A friend in need is a friend indeed.
A penny saved is a penny earned.
A watched pot never boils.
A stich in time saves nine.
Absence makes the heart grow fonder.
All is fair in love and war.
All that glitters is not gold.
All work and no play makes Jack a dull boy.
Beauty is in the eye of the beholder.
Beggars can’t be choosers.
Birds of a feather flock together.
Blood is thicker than water.
Don’t bite the hand that feeds you.
Don’t count your chickens before they hatch.
Don’t put all your eggs in one basket.
Don’t put too many irons in the fire.
Don’t talk the talk if you can’t walk the walk.
Don’t throw out the baby with the bath water.
Every cloud has a silver lining.
Fortune favors the bold.
Good things come to those who wait.
Great minds think alike.
Haste makes waste.
Hindsight is 20/20.
Honesty is the best policy.
Hope for the best, (but) prepare for the worst.
If it ain’t broke, don’t fix it.
If the shoe fits, wear it!
If you can’t beat ’em, join ’em.
If you snooze, you lose.
It never rains, but it pours.
Jack of all trades, master of none.
Keep your friends close and your enemies closer.
Leave no stone unturned.
Lie down with dogs, wake up with fleas.
Look before you leap.
Many hands make light work.
Measure twice, cut once.
Misery loves company.
Necessity is the mother of invention.
Never look a gift horse in the mouth.
Never put off till (until) tomorrow what you can do today.
No man is an island.
No pain, no gain.
Once bitten, twice shy.
One man’s trash is another man’s treasure.
Out of sight, out of mind.
People who live in glass houses should not throw stones.
Rome wasn’t built in a day.
Slow and steady wins the race.
Still waters run deep.
Strike while the iron is hot.
The early bird catches the worm.
The grass is always greener on the other side of the hill.
The pen is mightier than the sword.
The squeaky wheel gets the grease.
There’s no such thing as a free lunch.
Time and tide wait for no man.
Too many cooks spoil the broth.
Two heads are better than one.
Two is company, three is a crowd.
Two wrongs don’t make a right.
What goes around comes around.
What’s good for the goose is good for the gander.
When in Rome, do as the Romans.
When the going gets tough, the tough get going.
Where there’s smoke, there’s fire.
You can catch more flies with honey than with vinegar.
You can lead a horse to water, but you can’t make him drink.
You can’t have your cake and eat it too.
You can’t judge a book by its cover.
You can’t make an omelet without breaking a few eggs.
You can’t teach an old dog new tricks.
You reap what you sow.
Clichés, Phrases and Sayings (n = 25)

A wolf in sheep’s clothing
a dime a dozen
a sight for sore eyes
All roads lead to Rome.
All the world’s a stage, And all the men and women
merely players
blind as a bat
cool as a cucumber
He ran with his tail between his legs
I’m so hungry I could eat a horse!
last but no least
light at the end of the tunnel
Like sheep to the slaughter
One bad apple spoils the bunch.
Penny wise and pound foolish.
Revenge is a dish best served cold.
Separate the sheep from the goats
Stand out like a sore thumb
sweet smell of success
That’s the way the cookie crumbles.
The tail wagging the dog
the bottom line
The rest is history.
The tip of the iceberg
You lived your life, like a candle in the wind
You scratch my back, I scratch yours
In this chapter, we invite you to consider the role and function of technology in the discipline of visual art practice, and implications for interdisciplinarity. We present a reminder of technology’s grounding in and emergence from practice-based settings. We explore how attendance to technology’s practice-based roots can inform how we incorporate what we refer to as tangible technologies in junior high school (grade 7/8) Australian visual art and technology classroom settings. For evidence, we draw on recent interdisciplinary Doctoral research (Appendix) undertaken in an Australian University School of Education to explore how utilizing tangible technology can inform pedagogic and practice-based inquiry in Australian grade 7/8, or junior high school settings. In a time of active curriculum transition for teachers in Australian schools, our chapter advocates for teachers to return to the materiality of practice to inform curriculum enactment, learning area integration and interdisciplinary pedagogies.

INTRODUCTION

Teachers are well-practiced in adopting everyday items, such as recyclables, basic stationary, visual art media and craft materials for technological applications in the classroom. Technologies arise out of practice and of doing things with materials and can be conceived and used as a tool. In practice-based settings, teachers, artists and researchers alike engage and work directly with technologies to discover new ways of managing and manipulating material. This way of learning through doing and using technology to manage materials aligns powerfully with the processes and practices of doing arts-based research (ABR).

This chapter foregrounds tangible technologies as important and readily available classroom commodities. We describe how these are both physical and innovative, and contribute to the innovation trajectory of digital technologies. We use the term tangible technologies to define and consider the material attributes and applications of technology in practice-based settings. It is from the generative space of possibility we consider applications for tangible technology, and how they can be deployed in the classroom.

While the possibilities described in this chapter can be adapted for grades either side of our example, we describe specific ways tangible technologies can be utilised by teachers working with grade 7/8 visual art and technologies learning areas of the Australian Curriculum (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2022). We round out the chapter with examples of practical ways for teachers to use tangible technologies to integrate grade 7/8 visual art and technology content knowledge, and describe pedagogical implications for teachers.

RESEARCH REVIEW

In this chapter, we propose that tangible technologies have useful implications for how we teach visual art and technologies content in integrated ways. Technology is deeply rooted in art, and our purpose, in part, is to better acquaint teachers with the historical relationship between art and technology (Asia & Gordon, 2021; MacDonald et al., 2019).
Some of the benefits that arise when teachers engage tangible technologies include fostering connection and communication between disciplinary ways of knowing and doing (MacDonald & Beasy, 2022; Staten, 2019) and better supporting their students to innovate from the practice-based origins of design and technology (MacDonald et al., 2019). To do this effectively, teachers need to work in and with pre-digital (material), digital and post-digital ways of knowing and doing (Truman, 2022).

We can obtain a deeper understanding of the tangible roots of technology and its relationship with art and innovation by looking at its etymology. An *ology* is a branch of knowledge, with the original meaning of *techne* concerning the skills of the crafts and arts (Costa et al., 2019). Technology as a discourse or treatise is a form of scientific study of the practical or industrial nature of the arts (Marx, 2010). This history gives technology a deep synergy with the instruments and tools of the artist (Marx, 2010; Rutsky 1999). Working with clay, as is the case of the doctoral study examples referred to in this chapter (see Appendix), involves a literal struggle with the physical matter of art and technology. Clay as matter resists the artist’s efforts, requiring them to learn particular habits and skills, and develop tools specific to it and what they are attempting to create (Dewey, 2005; Hogan et al., 2018).

A particular ongoing challenge for technology research is to demonstrate the relationship between person, tool and environment in ways that are applied and materially authentic (Costa et al., 2019). A closer look into the materiality of visual art practice can alight ways for teachers to better understand and leverage a range of technological innovation for practice-based education enterprise.

**IMPLICATIONS**

As two artist, educator and research practitioner colleagues, we examine practice-based examples to highlight inter-relationships between theories and practices, and curriculum and pedagogies of visual art and technology. We proffer that it is not so much a question of whether or not research influences practice or vice-versa, but more a question of how we articulate the interrelationship in subject specific ways that are helpful for teachers. Teachers are already tasked with expectations of keeping in step with endless cycles of curriculum reform, and innovations in practice and pedagogy (MacDonald et al., 2016). A return to material engagement in and with practice is where teachers can playfully explore, reimagine and utilise technologies in tangible, embodied and sustainable ways.

For teachers to genuinely engage with research, it needs to be practical and applicable to the classroom setting. We have found that arts-based research (ABR) is eminently suitable for informing this, as it provides means to draw on a wide range of arts-based practices that inform research methodologies and teacher pedagogies (Brooke & MacDonald, 2022; Leavy, 2018; McNiff, 2018). We offer four implications of this for teachers working in junior high school (grade 7/8) settings. We explain these in context of their available insights and opportunities for teachers to interconnect research, practice, curriculum and pedagogy.

**Implication 1: Make the most of tangible technologies and everyday materials**

Teachers are experienced in using everyday materials as technologies to facilitate specific learning outcomes in the classroom setting. We suggest that what has been learnt historically about the application of technology in practice-based settings remains highly relevant for teaching and learning in junior high school settings. Our chapter focuses specifically on the grade 7/8 junior high school setting with potential to adapt further for grades either side of this context.

Teachers need practice-based opportunities to build, share and implement their tangible technologies toolkit. Tangible technologies in the school environment refer to everyday materials utilised by teachers. Tangibility is found in their physicality, adaptability, affordability and accessibility as a technology. For example, as described in our ceramics practice example (see Appendix, Figures 2 & 3), the tangible technology of the wooden paddle pop stick is used to enable air flow between tiles. This is essential for preventing tiles from warping during the drying process. Enabling air flow between tiles in the visual art ceramics classroom creates opportunity to integrate STEM (Science, Technology, Engineering and Mathematics) inquiry and learning.

In understanding the potential of the paddle pop stick as a tangible technology, teachers draw on the embodied knowledge of the arts practitioner. While art educators in Australia are well versed in leveraging technologies in their delivery of visual art and technology curriculum (Art Education Australia, 2020; Coleman & MacDonald, 2020), they
require ongoing opportunities to deepen and expand their own understandings of possibilities for the materials they work with. This helps build a sense of confidence and competence in how to leverage tangible technologies that are readily accessible for most teachers delivering visual art and design curriculum in Australia (ACARA, 2022).

**Implication 2: Embodied learning enables renewed understandings of materials and for integrated application of technologies**

Engagement with tangible technologies in ceramics enables generation, communication and evaluation of design ideas, and the use of materials, equipment and steps to safely make a solution for a purpose (AC9TDE8P03 [ACARA], 2022). It also offers a tangible practice-based example of investigating and trialling techniques, design technologies and visual arts processes used by artists. Due to its materiality, clay is a tangible technology that has the capacity to foster connections between visual art and design technologies content in the Australian Curriculum version 9.0 for years 7/8 (ACARA, 2022).

Clay and ceramics can facilitate embodied learning through the experience of rendering three-dimensional objects in the realms of science, such as replicating form to scale, and in the visual arts, for example sculptures. Reproducing three-dimensional forms in clay has the capacity to prepare the learner for understanding the simulated three-dimensional form of digital technologies such as computer assisted design (CAD). Clay can be used to create organic forms, such as human or animal, and prepare the learner for form creation that incorporates digital technologies across stages of planning and production. In this way, clay and ceramics continue to inform anatomic modelling innovation, forensic archaeology and three-dimensional printing.

When tangible technologies are embodied in visual art settings, teachers have opportunity to make authentic and applied connections between the research, theory and practice of both learning areas. In selecting, justifying and using suitable materials, components, tools, equipment, skills and processes to safely make designed solutions (AC9TDE8P03 [ACARA], 2022), artists, teachers and students alike can think about the ways in which processes and technologies have changed over time to arise from and impact on art-making (AC9AVA8E01 [ACARA], 2022). When teachers are encouraged to identify and attend to skill gaps in practice-based settings, they can re-think and re-imagine how different types of technologies can facilitate transformative learning, for themselves and their students (MacDonald & Coleman, 2020).

Historical connections between arts, crafts and technology can be made through embodied experiences of working with material matter in practice. It is therefore important that teachers be supported to explore and experiment with tangible technologies in ways that contribute to embodied knowing. When teachers achieve embodied understanding of tangible technologies, they can use it to foster creative problem solving around available teaching and learning resources, and to pursue authentic curriculum integration.

**Implication 3: Achieving curriculum enactment through practice-based learning area integration**

Ceramics practice provides an exciting foundation for teachers to consider where and how they can utilise technology in their enactment of integrated curriculum and pedagogies. To provide a practical example of opportunity and implications for teaching Visual Art content of Australian Curriculum version 9.0 (ACARA, 2022), we look to the ways in which ceramics entwine with technologies. The example documented in the Appendix shows a way for teachers to facilitate grade 7/8 content acquisition in both the Technologies and Visual Arts (The Arts) learning areas. For the visual arts, it offers opportunities to consider the development of visual art forms over time, and consideration of new discoveries in materials and technologies (AC9AVA10E01, [ACARA], 2022).

In context of the Design and Technologies subject for grade 7/8 students learning with Australian Curriculum (2022), the ceramic process also offers evidence of an opportunity to achieve integrated content inquiries. In order to achieve interdisciplinary learning outcomes via ceramic tile making, expert teacher input is required. Seeking such expertise encourages teachers to explore content from different disciplines, or learning areas.

In the example explored in this chapter, we alight opportunities for teachers to consider the utility of technology in visual art and other learning areas. There are many existing interdisciplinary pedagogical frameworks and education resources (MacDonald & Beasy, 2022) that can be adapted to support further pursuit of this. For example, the collaboratively developed STEMCrAfT Framework was designed to help out-of-field teachers harness the skills of expert STEM teachers (Beswick et al., 2016). These resources remain relevant and useful for teachers seeking to enact curriculum
through practice-based learning area integration, and it is important to draw teachers’ attention to these. Many of these have been helpfully gathered and curated into open access digital spaces for teachers to use and contribute to (Art Education Australia, 2020).

**Implication 4: Invite and encourage reciprocity between practice and research**

The further we venture into the realm of digital technology, tangible technologies will continue to provide novel settings for practitioners, researchers, teachers and learners to realise new perspectives on enduring problems. We have offered a reminder for how new technologies arise and evolve from older ones and extend from deep knowledge systems rooted in material and disciplinary practice. In examining how art practice incorporates tangible technologies, we have pointed to opportunities for grade 7/8 teachers to foster curriculum integration and embodied learning with tangible technologies in visual art settings. In so doing, we have explored how attendance to technologies in material settings can help teachers to develop embodied understanding of research informed practice, and practice informed research. When considered in connection to past practice, tangible technologies provide familiar contexts from which exploration of the unknown can be scaffolded for teachers and their students.

Simple, tangible technologies like the paddle pop stick can be used in ways that scaffold learning towards more complex ideas and specialist materials. For example, in your classroom setting you could explore the similarities and differences between the technological purpose of the paddle pop and the porcelain riser to open up possibilities for STEM centric learnings. Both paddle pop and porcelain riser are used to keep the tiles separate but each serves a particular purpose. The paddle pops help prevent warping of the tile form during drying by improving air flow, while the porcelain risers facilitate heat flow during the kiln firing. Due to their materiality, they do not distort under high temperatures. They are essentially a more ‘high tech’ version of the paddle pop, with the functional similarities and differences inviting learning about controlling air flow and temperature of a kiln firing. Because of its combined materiality and accessibility, the technological utility of the paddle pop stick has the capacity to be literally experienced and through the embodied learning process more easily understood.

When learning and teaching in art, we come to know by making things and using different materials. We are not arguing the utility of one technology over any other; rather, we have sought to demonstrate opportunities that arise when teachers work in and with a spectrum of technology in practice-based settings. Trajectories of technological innovation can be traced back to materiality and tangibility of practice (Asia & Gordon, 2021; Rutsky, 1999; Staten, 2019). We have sought to demonstrate how teachers, particularly those in the junior high school grade 7/8 setting, have rich opportunity to enact Australian Curriculum Version 9.0 Visual Art and Technologies learning areas in richly integrated and tangible ways. This is especially important for when teachers seek to incorporate new and emerging technologies into their classrooms. When teachers make tangible connections between research, theory, curriculum and pedagogies, they create opportunities to learn, unlearn, and learn anew (MacDonald et al., 2020).

In attending to materiality and reimagining technologies to support practice-based and embodied learning, visual art and technology learning areas present excellent opportunities for teachers to break down disconnects between research and practice and foster interdisciplinarity through authentic learning area integration. When teachers are supported to do this, they position themselves and their students to better understand how artists from the past and today are creating art and using technology to help them learn (Art Education Australia, 2020). Working with the tangible technologies of material practice can help teachers traverse and reconcile spaces between research and theory, and curriculum and pedagogy.

**REFERENCES**

Art Education Australia. (2020). Collaborative digital learning and teaching space. [https://docs.google.com/document/d/1-f6rOp0rTzuMpcW57FAGMnYcCHHM-AUhcsK1k2wM4_HQ/edit](https://docs.google.com/document/d/1-f6rOp0rTzuMpcW57FAGMnYcCHHM-AUhcsK1k2wM4_HQ/edit)


Coleman, K., & MacDonald, A. (2020). What are artists and art educators teaching us about how we can conceive and deliver teacher professional learning into the future? In R. E. Ferdig, E. Baumgartner, R. Hartshorne, R. Kaplan-Rakowski & C. Mouza (Eds.), Teaching, technology, and teacher education during the COVID-19 pandemic: Stories from the field (pp. 13–16). Association for the Advancement of Computing in Education.


Truman, S. E. (2023). Undisciplined: Research-creation and what it may offer (traditional) qualitative research methods. Qualitative Inquiry, 29(1), 95–104.

APPENDIX

Art practice involves working with materials, where practitioners engage bodily with matter in association with technology. In her 2023 practice-based doctoral research, Crowley (2023) used ceramic tiles to create an artwork based on the Fibonacci spiral as a way of visualising connections between visual art practice and STEM (science, technology, engineering and mathematics).

**Figure 1**

Crowley, S., *Unfurling Fibonacci*, 2021. Stoneware clay tiles fired to earthenware (1100°C), 195 x 315 cm

To create this work, clay was rolled flat, cut with a tile cutter, the tiles dried, bisque fired, decorated and glaze fired. Drying the flat clay tiles without warping requires management of the material using technology. Additionally, firing processes are constrained by the clay’s response to heating and cooling, which means that ceramic art practice is infused with skills involving the management of the material using available technology. This ceramic arts-practice setting provides innumerable STEM learning opportunities.
Technologies arise out of the fact that working with materials requires management of those materials, whether this technology be a computer or a paddle pop. The tangible technology involved in this instance included slab-roller, tile cutter, kiln, and the use of paddle-pop sticks and porcelain risers to aid airflow for drying and heat flow in firing and cooling.
Figure 3

Crowley, S., *Bisque fired clay tiles separated by porcelain risers to allow even heating and cooling*
GAMING, EXTENDED REALITIES, AND ROBOTICS
Digital games have the potential to support students’ mathematical understanding. However, the overuse of digital games, or the use of games that do not engage or enhance learning, can decrease students’ mathematical performance. Thus, it is vital that teachers select, evaluate and use digital games that engage and enhance student learning. Digital games that promote meaningful engagement motivate participation, increase mathematical focus, and support perseverance through appropriate levels of challenge. Digital games that enhance student understanding of mathematical ideas have features that allow for creativity in answers or strategies, engage multiple representations, increase active engagement through virtual manipulation of objects, or help support efficiency and precision. This chapter shares strategies teachers can use to select appropriate digital games, evaluate the features of games to determine whether a game may positively engage students or enhance mathematical understanding, and implement the games in classroom environments to increase student focus and mathematical connections.

INTRODUCTION

Digital games have the potential to engage students with mathematical ideas, increase perseverance for efficient practice, enhance understanding of mathematical concepts, and improve performance on mathematics assessments (Bullock et al., 2021; Moyer-Packenham & Litster, 2018). However, overusing digital games can lead to decreases in student performance, particularly for boys (Litster et al., 2020). Digital math games are comprised of two goals – the mathematical goals and the gaming mechanics goals. For example, in the Angle Asteroids digital game (see Figure 1), the mathematical goal is to identify the angle where asteroids are located, while the gaming goal is to shoot the asteroids.

When a game’s design is properly balanced, students can use their mathematical knowledge to achieve both goals (Litster & Moyer-Packenham, 2020). For example, in Angle Asteroids, students use their knowledge of angles to accurately rotate the ship and shoot the asteroids. However, when a game is not balanced, due to its design and affordances, the gaming design may obscure the mathematics or the heavy mathematics incorporation may limit students’ engagement and perseverance (Bullock et al., 2021). For this reason, it is important for teachers to carefully select digital math games that engage students in ways that focus on enhancing students’ understanding of the mathematics (Kolb et al., 2017; Moyer-Packenham et al., 2020). This can be done by carefully evaluating the features of digital games and implementing practices that improve student focus on mathematics while engaging with the digital games.
RESEARCH REVIEW

Research shows different features of digital games and different teacher practices can support students’ meaningful engagement with the games and enhance understanding of mathematical concepts in the games. Features that support meaningful engagement motivate students to play the game, increase mathematical focus, and encourage perseverance through appropriate levels of challenge (Kolb, 2017; Litster et al., 2019). While reward features entice students to begin playing a game, games with meaningful applications of the mathematics are more likely to encourage continued student engagement (Mekler et al., 2013). Features that provide feedback beyond right/wrong help students make connections and persevere through challenges to increase learning (Bullock et al., 2021). Features of digital games that enhance student understanding of mathematics allow for creativity, engage students with multiple representations, actively interact with or manipulate objects virtually, or support efficiency and precision (Bullock et al., 2021; Kolb, 2017; Litster & Moyer-Packenham, 2020; Moyer-Pakenham et al., 2020; Moyer-Packenham et al., 2019).

Teacher practices that increase student focus during digital game play include introducing the features and mathematical connections before game play and debriefing student strategies to achieve mathematics goals after game play (Wouters et al., 2013). During gameplay, teachers can provide instruction supports and scaffolding or set up collaborative discourse opportunities to increase student focus (Litster & Macdonald, 2022). When students work together, it increases opportunities to explore multiple strategies, engage in higher-order thinking, and persevere through challenges. Specific strategies to evaluate digital games and to implement teacher practices are provided in the implications section of this chapter.

IMPLICATIONS

There are three stages to using digital games in ways that engage and enhance student learning: 1) finding digital math games; 2) evaluating game features; and 3) implementing games in classroom environments.

Selecting Digital Games

The first step when selecting digital games is to determine which platform(s) work best for your classroom. Touchscreen devices increase physical interaction and sensory movements with direct touch, trace, or drag interfaces. These build sensory-motor skills and physical memory mapping of mathematics concepts such as shapes and numbers. Online games are accessed via laptop or desktop computers. Ensure you have a mouse for ease of use with interactive features in computer-based digital games.
After choosing a platform, check with your school or district technology specialist to determine restrictions on websites or subscriptions and procedures to request one-time purchases or on-going subscriptions. Your technology specialist may have a list of mathematics games or subscriptions used by other teachers in the district to start your search.

Search engines are a great resource to locate digital games based on content. Searching by content rather than grade-level brings forward lesser-known resources. You can refine searches with key terms such as “online” and “digital” to differentiate between physical and digital games, “free” to bring up games with no costs, or “virtual manipulative” to focus on games with interactive features. Some companies design multiple games. When you find a high-quality game, check the associated website for potential digital games in other content areas. You may also consider ratings, reviews, or feedback about the games to determine if there are any known issues with quality of the games or age inappropriate components such as frequent advertisements or links to third-party websites. A list of potential games companies with a history of high-quality games can be found in Appendix A.

Evaluating Game Features

While there are numerous high-quality digital mathematics games for young children (Pre-K to Grade 2), the number of high-quality games decreases as children age. Evaluating game features helps determine which game designs engage and enhance mathematical learning. An evaluation checklist can be found in Appendix B.

Engage

First, ask yourself: Would this game motivate my students to start and continue playing (Kolb, 2017)? Look at the general layout for the game (e.g., character or object design style, color scheme, font style and size) for readability, usability, and age-appropriateness. Play through the game and consider whether the game provides external rewards (coins, stars) or internal rewards (meaningful play) (Mekler et al., 2018). Internal rewards are more likely to motivate students to continue playing over time. As you play through the game, consider whether the design of the game is tutorial (guiding information on procedures), gaming (levels, points, goals), or simulation (animated application model) (Moyer-Packenham & Litster, 2018). Each game-type has benefits and drawbacks for motivation. For example, tutorials can support struggling students, but often slow down or frustrate more advanced students. Simulations have high transfer of learning, but often need more teacher instructions to focus exploration.

Next, ask: Are there any features that might distract student focus from the mathematics? (Kolb, 2017). As you play through the game, note the strategies and knowledge you use to “win” the game. If no mathematical thinking or strategies are required to be successful, the game design is imbalanced and does not engage students as intended (Litster & Moyer-Packenham, 2020). Avoid games with timers or look to see if the timer feature can be turned off. Timers can increase anxiety for struggling students, affecting their mathematical thinking, while advanced students are more likely to “game” the system and bypass mathematics to increase speed (e.g., randomly click answers if no penalty for incorrect responses).

Third, ask: Which of my students would find this to be an appropriate level of challenge? (Litster et al., 2019). Intentionally make mistakes as you play the game to observe the types (or lack) of hints, prompts, or feedback available to support struggling students (Bullock et al., 2021). Evaluate whether these features will help or cause more confusion. Play the game again, going through quickly to identify any features that slow down or hinder progress for advanced students. Explore the settings to determine which features may be adjusted to support multiple levels of challenge. Finally, consider whether all or only some of your students can engage with the game at their own level of challenge, to achieve success (Litster et al., 2019).

Enhance

Digital games that enhance learning deepen student understanding, encourage mathematical connections, and support transfer to out-of-game contexts (Kolb, 2017; Litster & Moyer-Packenham, 2020). Teachers can evaluate how well digital games enhance learning by looking for four types of design features: creativity, multiple representations, virtual manipulation, and efficiency/precision.
First ask: Does this game allow students to use creative answers or strategies to demonstrate mastery? (Litster & Moyer-Packenham, 2020). For example, Chicken Coop Painter asks students to fill half of a 4x4 grid. As long as 8 of the 16 boxes are filled (horizontal, vertical, or random), the student is successful. There may be features that change the level of creativity. For example, in ABCYa!’s Learn to Count Money game, selecting “beginner” allows students to use multiple combinations to represent the total, whereas “expert” provides feedback indicating a correct total but redirects students to find the most efficient combination.

Second ask: Does this game help students make connections between multiple representations? (Moyer-Packenham et al., 2019). Consider both the representations the digital game provides (e.g., auditory names or numbers, visual images of mathematics, 3-D models that can be rotated, abstract numbers) and the representations students create (e.g., writing numbers, drawing pictures, building models). Avoid games where students do not create any representations (e.g., says or displays totals from a model as it is created), evaluate the accuracy of the representation as it is animated. When playing quickly, does the animation fall behind showing inaccurate mathematics representations?

Third ask: Does this game allow students to virtually engage with or manipulate objects? For example, Dragon Box Elements is a touch-screen game where students physically trace geometric shapes and move pieces around to identify elements such as equivalent sides and angles. Look for games with dynamic, interactive features such as in-game objects that use or mimic physical math manipulatives (Moyer-Packenham et al., 2020). For example, Montessori Numbers Base-10 Blocks has a number building game using virtual base-10 blocks. Blocks can be moved around, organized, counted, added, or removed. ABCYa has a similar game with snakes that mimic the blocks.

Fourth ask: Are there features that improve student precision or efficiency? The expert mode on the ABCYa money game is one example that encourages efficiency. TopMarks has a Measuring in Centimetres game that allows students to use a movable bar to precisely and efficiently measure objects with shapes that are not flat, such as scissors or a ball. PhET Simulations’ suite of fraction games make precise divisions of a variety of fractional shapes and number lines based on student-selected settings to precisely and efficiently create simple fractions, mixed fractions, or equivalent fractions.

Not all games will have every enhancement feature. Additionally, simply having a large number of enhancement features does not necessarily make a gamer higher quality; consider how the balance of digital and mathematics features support the learning goals. Choose a variety of games with different enhancements to support different aspects of student learning or practice.

**Teacher Practices when Implementing Games**

Students’ awareness of helping features increases both in-game and out-of-game success with the mathematics (Bullock et al., 2021). Four implementation strategies that increase student awareness and focus are introductions, debriefs, instructional supports, and collaboration.

When introducing the game to your students, point out specific design features promoting mathematics learning, connections, and representations (Litster et al., 2020; Litster & Moyer-Packenham, 2020). Make sure you provide enough information to help students identify potential strategies, supports within the game, and make mathematical connections; but not so much information that it stifles students’ creativity or critical thinking. For example, in Angle Asteroids (Figure 1), you might introduce the two different places the angle is displayed when moving and releasing the slide bar and the benchmark angles every 90 degrees.

After students engage with the digital math game, use reflective discourse to debrief student strategies and discoveries while playing the game (Wouters et al., 2013). This is a great way to solidify key ideas, strategies, and connections you want students to learn or practice within the digital game. This process can also help you assess if the game met your expectations for the levels of engagement and enhancement of student learning outcomes. For example, after playing the Angle Asteroids game, you might want to hear student strategies such as using labeled asteroids as additional benchmarks or estimations to increase accuracy, indicating alignment with objectives, rather than randomization strategies. Have students consider which strategies can be applied outside the game to highlight connections and learning targets.

Use instructional supports when students play the digital mathematics game independently. Guided instructions focus students toward different helping features within the digital game to provide additional supports or challenges. This may include choosing specific levels or activities at different levels of challenge, adjusting specific in-game features to
help students make connections, focus on the mathematical concepts, or balance gaming-heavy designs (Litster et al., 2019). You may also want to bring in additional resources to scaffold learning such as posters, reference pages, whiteboards/scratch paper, or aligned worksheets where students document the mathematical strategies and representations used to address challenges within the game (Litster et al., 2019). Samples of Aligned worksheets are in Appendix C.

Use collaboration to increase student focus and attention on the mathematical ideas in the digital game. Sharing a single device between multiple students can conserve resources if you are not in a one-to-one device classroom or have limited licenses for purchased games. Collaborative discourse allows students to discuss different strategies for success as they negotiate control over what happens within the game (Litster & MacDonald, 2022). You may choose to group students with similar ability levels to provide focused levels of challenge, with different ability levels to provide an instructional support, or different strategy/representation preferences to increase connections.

REFERENCES


### Potential Game Companies or Websites

Please remember that not all games by the same company or site will have the same features for engagement or enhancement. Be sure to evaluate any game for use in your unique classroom.

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Description</th>
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<tbody>
<tr>
<td>ABCYa!</td>
<td>Has a variety of math games based on virtual manipulatives and multiple representations.</td>
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<tr>
<td></td>
<td><a href="https://www.abcya.com/">https://www.abcya.com/</a></td>
</tr>
<tr>
<td>DragonBox</td>
<td>This company has joined the Kahoot! Family. They offer a variety of interactive games on touchscreen devices. The games require one-time purchases and are free of advertisements.</td>
</tr>
<tr>
<td></td>
<td><a href="https://dragonbox.com/">https://dragonbox.com/</a></td>
</tr>
<tr>
<td>FunBrain</td>
<td>While many of the games overly focus on the “fun” in the games rather than building math skills, there are a few games such as cake monster that encourage precision.</td>
</tr>
<tr>
<td></td>
<td><a href="https://www.funbrain.com/math-zone">https://www.funbrain.com/math-zone</a></td>
</tr>
<tr>
<td>Mr. Nussbaum</td>
<td>Most operations are type in or click on answer only. However, many of the other content areas have multiple representations or creativity.</td>
</tr>
<tr>
<td></td>
<td><a href="https://mrnussbaum.com/math">https://mrnussbaum.com/math</a></td>
</tr>
<tr>
<td>Montessori</td>
<td>This company has a variety of early childhood (Pre-K-2) apps for touchscreen devices. The games require one-time purchases and are free of advertisements. Search “Montessori” on your device.</td>
</tr>
<tr>
<td>PBSkids</td>
<td>The math games focus on pre-k and early elementary math skills with characters from PBS educational shows.</td>
</tr>
<tr>
<td></td>
<td><a href="https://pbskids.org/games/math">https://pbskids.org/games/math</a></td>
</tr>
<tr>
<td>PhET Simulations</td>
<td>Has a variety of simulations that require teacher-created tasks to focus exploration as well as digital games that use the simulations.</td>
</tr>
<tr>
<td></td>
<td><a href="https://phet.colorado.edu/">https://phet.colorado.edu/</a></td>
</tr>
<tr>
<td>Sheppard Software</td>
<td>While most games are just clicking a correct answer, there are a few games matching multiple representations or allow for creativity.</td>
</tr>
<tr>
<td></td>
<td><a href="https://www.sheppardsoftware.com/math.htm">https://www.sheppardsoftware.com/math.htm</a></td>
</tr>
<tr>
<td>SolveMe Mobiles</td>
<td>Students can play with digitally created algebra mobiles or build their own models of balanced equations.</td>
</tr>
<tr>
<td></td>
<td><a href="http://solveme.edc.org/mobiles/">http://solveme.edc.org/mobiles/</a></td>
</tr>
<tr>
<td>Virtual Manipulatives</td>
<td>While virtual manipulatives themselves are just mathematical tools that require teacher-created tasks to focus student actions, many sites have tutorials, practices, or games aligned to virtual manipulatives that provide digitally created tasks.</td>
</tr>
<tr>
<td></td>
<td><a href="https://toytheater.com/category/teacher-tools/virtual-manipulatives/">https://toytheater.com/category/teacher-tools/virtual-manipulatives/</a></td>
</tr>
<tr>
<td></td>
<td><a href="https://www.geogebra.org/m/NPDu3rCm">https://www.geogebra.org/m/NPDu3rCm</a></td>
</tr>
<tr>
<td></td>
<td><a href="http://nlvm.usu.edu/en/nav/vlibrary.html">http://nlvm.usu.edu/en/nav/vlibrary.html</a></td>
</tr>
<tr>
<td></td>
<td><a href="https://www.mathlearningcenter.org/resources/apps">https://www.mathlearningcenter.org/resources/apps</a></td>
</tr>
<tr>
<td></td>
<td><a href="https://www.nctm.org/Classroom-Resources/Illuminations/Interactives/">https://www.nctm.org/Classroom-Resources/Illuminations/Interactives/</a></td>
</tr>
</tbody>
</table>
## APPENDIX B

**Evaluation Checklist**

### ENGAGE STUDENTS

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would this game motivate my students to start and continue playing?</td>
<td></td>
</tr>
<tr>
<td>The general layout is readable, usable, and age-appropriate</td>
<td></td>
</tr>
<tr>
<td>The game motivates through meaningful application of math</td>
<td></td>
</tr>
<tr>
<td>The game design is appropriate for students in my class: tutorial (guiding play); gaming (levels, points, goals); or simulation (animated application mode).</td>
<td></td>
</tr>
<tr>
<td>This game will motive the following student(s) in my class.</td>
<td></td>
</tr>
</tbody>
</table>

### Are there any features that might distract student focus from the mathematics?

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The game cannot be “won” without knowing or solving the math.</td>
<td></td>
</tr>
<tr>
<td>There are no advertisements or animations that distract focus.</td>
<td></td>
</tr>
<tr>
<td>There is no countdown timer (or timer can be turned off).</td>
<td></td>
</tr>
<tr>
<td>The features in or around this game allow the following student(s) to focus on the math:</td>
<td></td>
</tr>
<tr>
<td>Would collaboration using a single device support or detract focus on the mathematics?</td>
<td></td>
</tr>
</tbody>
</table>

### Which of my students would find this to be an appropriate level of challenge?

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>There hints, prompts or feedback when mistakes are made to redirect students for accuracy or efficiency.</td>
<td></td>
</tr>
<tr>
<td>There are no features that slow down or hinder progress for advanced students.</td>
<td></td>
</tr>
<tr>
<td>This game is an appropriate challenge for the following student(s)</td>
<td></td>
</tr>
<tr>
<td>Which features would you want to introduce before gameplay?</td>
<td></td>
</tr>
<tr>
<td>What features would you want to turn on/off or external resources would you want to provide to prove an appropriate level of challenge for different students?</td>
<td></td>
</tr>
</tbody>
</table>

### ENHANCE (Includes at least 1)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The game allows students to use creative answers or strategies to demonstrate mastery.</td>
<td></td>
</tr>
<tr>
<td>The game has students make connections between two or more representations (sounds, images, models, numbers, symbols, words)</td>
<td></td>
</tr>
<tr>
<td>If the game provides automatic representations, the animation accurately represents the math regardless of speed.</td>
<td></td>
</tr>
<tr>
<td>The game encourages precision or efficiency.</td>
<td></td>
</tr>
<tr>
<td>Which features would you want to introduce before gameplay to focus on creativity, representation connections, precision, or efficiency?</td>
<td></td>
</tr>
<tr>
<td>What strategies would you want to hear about during a debrief after gameplay?</td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX C

**Sample Worksheets Aligned to Digital Games**

### Algebra Solve-It Mobiles Worksheet

<table>
<thead>
<tr>
<th>Expression 1</th>
<th>Expression 2</th>
<th>Expression 3</th>
<th>Expression 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Draw a picture of your balanced model.</td>
<td>Draw a picture of your balanced model.</td>
<td>Draw a picture of your balanced model.</td>
<td>Draw a picture of your balanced model.</td>
</tr>
</tbody>
</table>

### Sweet Treats Worksheet

- Name: __________
- Please write down how you solved the first six problems on the game.

https://www.cs.research.slu.edu/CeÌ²/Scprevious/
APPENDIX D

Recommended Readings or Resources for More Information

Choosing Digital Games


Engaging and Enhancing Student Learning


Teacher Practices

Using a Motion Simulator to Support Learning About Linear Functions

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Computer simulations can be supportive in helping students explore concepts. Here, a motion simulator is used to contextualize the slope–intercept equation in beginning algebra; the simulator is available on the internet and is free to use for all. The simulator portrays a man “walking” along a horizontal $x$–axis with varying speed and direction, accompanied by position/time and velocity/time graphs to represent the motion. The simulator can assist students as they explore the relationships between the man’s motion and the corresponding graphs, along with the mathematical equations associated with the graphs. Emphasis is on how the $y$–intercept relates to a person’s starting point and how speed and direction relate to slope. There are three ways to use the simulation: toggling (moving) the man, entering an equation, or entering values. The last two methods create movements that can be modeled by straight lines to which the slope–intercept formula can be applied. Two activities are provided that utilize straight–line graphs to promote a context for understanding the meaning of the components of the slope–intercept formula. Activities are designed for introductory algebra (middle school or early high school content).

**INTRODUCTION**

Simulations are often used in science, technology, engineering, and mathematics (STEM) to help students visualize phenomena. Simulations can be fruitful because they allow students to make conjectures, run repeated trials, gather data, make adjustments, and iteratively try again. Particularly in mathematics, simulations have a positive effect on student outcomes (Hillmayr et al., 2020). Rakes et al. (2010) conducted a systematic review of educational studies ($N = 82$) that had shown instructional improvements in algebra. They found that technology–based algebra curriculum and the use of technology were two of five categories that improved student achievement.

Using simulations can help students visualize motions that are modeled by equations, and also help them to explore what the components of the equations represent. A free physics–based motion simulation is used to contextualize algebra with a particular emphasis on the slope–intercept formula. For example, in the slope–intercept equation ($y = mx + b$), the value of $b$ can be seen to be associated with the initial position of the man who is shown as moving in the simulation; the value of $m$ can be observed to be associated with the slope of the position/time graph, in which case it represents *velocity*, and also with the slope of the velocity/time graph, in which case it represents *acceleration*. Two lessons are provided that interactively explore how to use the physics–based simulation to teach slope and $y$–intercept to students as they learn basic algebra. Emphasis is on how the man’s starting point and velocity impacts the structure of the slope–intercept equation used to model the motion. Step–by–step instructions for using the simulation are included in the lessons designed for introductory algebra (middle school or early high school content).

This curriculum was designed by integrating movement and technology to provide meaningful contexts to learn key algebraic concepts of slope and rate of change. By engaging in this curriculum, students can experience opportunities to develop the concept of slope in context and understand formulaic meanings for slope. With support of the images, there is a connection between the physical movement and the changes on a position/time graph.
RESEARCH REVIEW

Challenges in understanding the meaning of slope are well documented across a multitude of learners. In relation to eighth and ninth grade students in the United States, Korea and Israel, Greenes et al. (2007) identified difficulties across a multitude of concepts including identifying negative/positive slopes, recognizing scale factors on the axes, describing the connection between speed and time, and a relying on visual perceptions rather than calculations. Algebraic symbolism, or the use of symbols in algebra to represent quantitative situations and to support the communication of ideas (Kieran, 1996; Pitta–Pantazi et al., 2020) can also be quite challenging for secondary students (Molina et al., 2017).

With student challenges of algebra concepts like slope, scale and speed/time connections, teachers need to proactively seek alternative approaches for richer experiences. Technology is generally highly accessible in the United States and, though the use of simulations, can be a cost–effective way to supplement more traditional algebra instruction. Simulations in mathematics can be “defined as a way to simulate a scientific and/or complex system” by embedding mathematical content into an environment (Pan et al., 2022). Using simulations in algebra has been shown to increase students’ interest compared to more traditional instruction (Egara et al., 2022). Moreover, simulations can improve students’ development of algebraic thinking (de Castro Filho et al., 2021).

For the activities presented here, a specific simulation to support physics instruction is used to contextualize algebra. The simulation used in the lessons is a creation of the University of Colorado, Boulder and is part of the Physics Education Technology (PhET) library (https://phet.colorado.edu/en/simulations/filter?type=html,prototype). The PhET library includes simulations in physics, chemistry, mathematics, earth science, and biology. There are over 100 simulations that are searchable by subject, grade level, and inclusive features with a plethora of language options. This database of simulations is reliable, evolving and well–known for enhancing STEM learning (Wieman et al., 2008). The simulations within the database have been widely researched, generally showing improvements in attitudes, engagement and understanding of concepts (Adams, 2010; Haryadi & Pujiastuti, 2020; Yunzal & Casinillo, 2020).

IMPLICATIONS

To support the development of position/time and velocity/time graphs, an online simulation called The Moving Man was used (https://phet.colorado.edu/sims/cheerpj/moving-man/latest/moving-man.html?simulation=moving-man). An easy way to access the simulator is searching the term “The Moving Man.” There are three ways to use The Moving Man simulation: toggling (moving) the man using a mouse or trackpad, entering an equation, or entering values. The last two methods create movements that can be accurately modeled by straight–line graphs and to which the slope–intercept formula may be applied, without the need for estimates of values.

To integrate simulations into a secondary algebra class, there needs to be a purposeful use of the simulation. In other words, activities need to be designed and implemented that encourage the use of the interactive features to support meaningful explorations emphasizing sense making (Hillmayr et al., 2020). Encouraging students to interact with the simulation by testing, evaluating, adjusting and retesting conjectures can support more meaningful simulation experiences. de Castro Filho et al. (2021) recommend three distinct strategies for using simulation technologies to improve algebraic reasoning. Simulations should be used to showcase multiple representations of concepts (i.e., graphs, tables, symbols, images). Second, the manipulation of a character or object should be used to test and evaluate conjectures. Third, artifacts should be produced and collaboratively used and reflected upon.

Toggling

To toggle the man, the mouse or trackpad can be used to move him along the horizontal track by clicking on him and then moving the mouse. There are constraints with this method, as it is impossible to get corresponding motion graphs consisting of smooth straight lines. Therefore, in these cases, graphs of simple equations will not align well with the lines on the motion graphs; see Figure 1. To familiarize students with the features of the simulation, they might be prompted to explore it with the following instructions:

- Click on the “Charts” function to activate the charts, deselect acceleration (if applicable).
● Create a position/time graph with a constant negative slope. What are the values of the slope and y–intercept? How do these values correspond to the man’s movement?
● Create a position/time graph with a constant positive slope. What are the values of the slope and y–intercept? How do these values correspond to the man’s movement?
● Create a position/time graph in the shape of mountain that is steep on the left side and less steep on the right side. How is the steepness of the mountain reflected in the slope? How did the man’s motion relate to the steepness?
● Create a position/time graph in the shape of three consecutive mountains: a small mountain, a large mountain, and then another small mountain. How is the steepness of the mountains reflected in the slope? How did the man’s motion relate to the steepness?
● Describe relationships between the velocity/time graph and the position/time graph.

Figure 1

Position and velocity graph created by toggling (Meltzer, 2023a)

Entering an Equation

Smooth lines can be created in the simulation by entering an equation. To create a movement using an equation, see Figure 2.

● Click on the “Charts” function to activate the charts, deselect acceleration (if applicable).
● Click on the “Special Features” menu and then on the “Expression Evaluator” function; deselect acceleration (if applicable).
● Enter the function as shown above: $2 \cdot t - 5$. This is how $y = 2x - 5$ would be entered. Note $t$ is used rather than $x$.
● Then, push the play button in the Expression Evaluator box.
Appendix A includes more detailed instructions as well as a worksheet with open-ended questions to support student explorations using equations. To expand on the lesson in the appendix, students can be asked to:

- Create two position–time graphs: one with a constant negative slope and one with a constant positive slope. What are the values of the slope and y–intercept in your two graphs? How do these values correspond to the man’s movement? How do negative and positive values influence the slope and y–intercept?
- Create a position/time graph that starts at –12 m and progresses to 12 m within an 18–second timeframe. Describe the values of the slope and y–intercept. If the graph starts instead at 12 m and progresses to –12 m in an 18 second timeframe, how is the equation impacted? If the graph starts at –6 m and progresses to 6 m in an 18–second timeframe, how is the equation impacted?
- Enter an equation of your choice that results in a motion lasting longer than 10 seconds. What is the slope and y–intercept of your equation? Examine the corresponding velocity graph. Explain how the velocity graph relates to the equation.
- Enter an equation into the simulator. Once the position/time and velocity/time graphs are created, cover up the position graph with a piece of paper. Ask a classmate to determine the equation you used by looking only at the velocity graph. Is it possible? Explain your reasoning.

Figure 2

*Position and velocity graphs created by entering an equation (Meltzer, 2023b)*
Entering Values

In addition to equations, values can be entered into the simulation to create straight lines that represent movement. To create lines using values:

- Click on the “Charts” function to activate the charts, deselect acceleration (if applicable).
- There is a box under the word “Position.”
- Put a 5 in the “Position” box and a −3 in the “Velocity” box, as shown below in Figure 3.
- Hit Play (the button with a circle).
- Watch the man move, then when he reaches the wall, push the “Pause” button. Try to stop him before he hits the wall and stops.
- After you pause the man, change the “Velocity” to 3 and then again push “Play.” Watch the man move, then when he reaches the wall, push the “Pause” button. Try to stop him before he hits the wall and stops.
- Now, switch the velocity to −7 and push play. Pause him before he hits the wall.

Appendix B includes more detailed instructions as well as a worksheet with open-ended questions to support student explorations using values. To expand on the lesson in the appendix, students can be asked to:

- Create two graphs: one with a constant negative slope and one with a constant positive slope. Can an equation be created based solely on the graphs? Explain your reasoning.
- Enter an equation of your choice that generates a motion that lasts longer than 10 seconds. What is the slope and y–intercept of your equation? Examine the corresponding velocity/time graph. Explain how the velocity graph relates to the equation.
- Enter values into the simulator. Once the position and velocity graphs are created, cover up the velocity graph with a piece of paper. Ask a classmate to sketch the velocity graph using the position graph image. Is it possible? Explain your reasoning.

Figure 3

*Position and velocity graphs created by entering values (Meltzer, 2023c)*
Extension

Creating equations or identifying the values requires a different perspective, perhaps a deeper understanding of the components that influence a position graph and a velocity graph. Students can be challenged to create replicas of graphs by entering equations or entering values. An example from the appendix can be seen in Figure 4. Students can be asked to manipulate the numbers entered into the “Position” and “Velocity” windows, to try to create the given graph. The solution can be found by starting with a zero for position and a velocity of –7 m/s. Then, once the man hit the wall, velocity was changed to 0.25 m/s. Finally, when the man walked for about 18 seconds total, velocity was changed to 7 m/s. Additionally, students can be asked to:

- Create a graph using values and share the graphs with classmates. The values or equations can be covered up. Classmates are then challenged to create the exact same graph by generating their own equation.
- Create a graph using values and share the values with classmates; the graphs can be covered up. Classmates are then challenged to conjecture the shape of, then sketch the graph that will be created by the given values.

Figure 4

Using the graphs, generate corresponding equations (Meltzer, 2023d)

Some general questions to ask for all of the activities include:

- How do you know where to position the man at the start?
- How does slope relate to velocity?
- What does the man’s starting position represent?
- How do you know if velocity is positive or negative?
- How do you know what number to try for velocity (a large number or a small number)?
- Can you determine velocity using a formula?
ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. 1855891. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

REFERENCES


APPENDIX A

Exploring Equations using the Motion Man Simulation

Using the Simulation with Equations:

2. Click on the “Charts” function to activate the charts, deselect acceleration of applicable.
3. Click on the “Special Features” menu and then on the “Expression Evaluator” function; deselect acceleration (if applicable).
4. Enter the function as shown above: 2 * t – 5. This is how \( y = 2x - 5 \) would be entered. Note \( t \) is used rather than \( x \).
5. Then, click the blue play button in the Expression Evaluator box seen in Figure 1.

Figure 1

*Position and velocity graphs created by entering an equation (Meltzer, 2023b)*

---

6. What does the \( t \) represent?
7. What does the \(-5\) represent? How would the graph be different if the 5 was positive?
8. How long did it take to get to the wall near the house?
9. If the 2 became a 4, how would the line look different?
APPENDIX B

Exploring Values using the Motion Man Simulation

Using the Simulation with Equations:

2. Click on the “Charts” function to activate the charts, deselect acceleration if applicable.
3. There is a box under the word “Position”, see Figure 2.
4. Put a 5 in the “Position” box and a −3 in the “Velocity” box, as shown below.

Figure 2

Setting up the moving man simulation for equations (Melzer, 2023e)

5. Click the blue play button. Watch the man move, then when he reaches the wall, push the “Pause” button. Try to stop him before he hits the wall and stops.
6. After you pause the man, change the “Velocity” to 3 and again push “Play.” Watch the man move, then when he reaches the wall, push the “Pause” button. Try to stop him before he hits the wall and stops.
7. Switch the velocity to −7 and push play. Pause him before he hits the wall, see Figure 3.
Figure 3

*Position and velocity graphs created by entering values (Meltzer, 2023c)*

8. Here are some questions to consider:
   a. We changed the velocity from –3 to positive 3, how did that impact the position/time graph? The velocity/time graph?
   b. The position/time graph is steepest at the end; why?
   c. The velocity/time graph has horizontal lines; why?
   d. How do the position/time graph relate to the velocity/time graph?
   e. By manipulating the numbers entered into the “Position” and “Velocity” windows, try to create an image that looks like Figure 4.

Figure 4

*Using the graphs, generate corresponding equations (Meltzer, 2023d)*

   i. Explain how you created your image.
   ii. How does the number you put into the “Velocity” window impact the graph with the blue line (the position/time graph)?
# APPENDIX C

## Free Simulations to Support Learning of Algebraic Concepts

<table>
<thead>
<tr>
<th>Name</th>
<th>Website Address and Description</th>
<th>Algebra I Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graphing Lines</strong></td>
<td>Available: <a href="https://phet.colorado.edu/sims/html/graphing-lines/latest/graphing-lines_all.html">https://phet.colorado.edu/sims/html/graphing-lines/latest/graphing-lines_all.html</a> Allows user to graph straight lines using the point-slope formula and the slope-intercept formula, as well as to play games by creating graphs to match computer-generated equations.</td>
<td>Students can develop understanding of straight-line graphs through a variety of mathematical representations and contexts, by varying the values of slope and intercept and observing the associated changes in the graphs.</td>
</tr>
<tr>
<td><strong>Graphing Quadratics</strong></td>
<td>Available: <a href="https://phet.colorado.edu/sims/html/graphing-quadratics/latest/graphing-quadratics_all.html">https://phet.colorado.edu/sims/html/graphing-quadratics/latest/graphing-quadratics_all.html</a> Allows user to create graphs of quadratic functions in both standard and vertex form, interactively adjusting coefficients to explore changes in graph structure.</td>
<td>Students can explore graphs of quadratic functions by interactively varying coefficients of terms in the quadratic equation and observing changes in the associated graphs.</td>
</tr>
<tr>
<td><strong>Resistance in a Wire</strong></td>
<td>Available: <a href="https://phet.colorado.edu/en/simulations/resistance-in-a-wire">https://phet.colorado.edu/en/simulations/resistance-in-a-wire</a> User can adjust values of variables in the resistance equation $R = \rho L / A$ to observe resulting visual changes in magnitude of $R$.</td>
<td>Students can explore meaning of direct and inverse proportionality by varying values of one or more of the parameters $\rho$, $L$, and $A$ in the resistance equation and observing representations of the resulting changes in magnitude of $R$.</td>
</tr>
<tr>
<td><strong>Equality Explorer: Two variables</strong></td>
<td>Available: <a href="https://phet.colorado.edu/sims/html/equality-explorer-two-variables/latest/equality-explorer-two-variables_all.html">https://phet.colorado.edu/sims/html/equality-explorer-two-variables/latest/equality-explorer-two-variables_all.html</a> Allows user to create and solve two-variable equations by varying coefficients and observing effects on a “balance scale” that compares the two sides of the equation.</td>
<td>Students can explore the meaning and structure of two-variable equations by finding solutions when the form of the equation is fixed or by modifying the form of the equation when the solutions are fixed.</td>
</tr>
<tr>
<td><strong>Gravity-Force Lab</strong></td>
<td>Available: <a href="https://phet.colorado.edu/en/simulations/gravity-force-lab">https://phet.colorado.edu/en/simulations/gravity-force-lab</a> User can explore Newton’s Law of Universal Gravitation $F = m_1 m_2 / r^2$ by varying values of the masses $m_1$ and $m_2$ as well as the separation distance $r$. Resulting magnitude of force $F$ is represented by the lengths of vector arrows.</td>
<td>Students can explore meaning of quadratic and linear variation by selectively varying parameters in the gravitational force law and viewing representations of the resulting magnitude of the gravitational force.</td>
</tr>
</tbody>
</table>
Digital-Based Video Games and 21st Century Skills

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In our current society, the development of 21st century skills is essential to be successful in one’s professional and personal life. Current 21st century skills refer to both hard skills (e.g., math skills, programming skills, design), as well as soft skills (e.g., communication, collaboration, critical thinking, and creativity). When students engage with these skills in the classroom, they are better equipped to function in their day-to-day lives as they apply these skills in everyday tasks. Determining the ways to implement such skills into the curriculum, however, can be challenging. The use of digital-based video games in the classroom can provide educators the opportunity to engage students in activities that support the development of 21st century skills while simultaneously maintaining a focus on key curricular goals. The goal of this chapter is to provide examples of the ways digital-based video games help develop 21st century skills and to provide lesson ideas for incorporating digital-based video games in the classroom.

Keywords: digital-based video games; 21st century skills; problem solving; creativity; collaboration; K–12 education

INTRODUCTION

There is an increased global interest in helping K–12 students develop 21st century skills. However, it is difficult to ensure development of 21st century skills in education because of the increased emphasis on more academic skills alone. 21st century skills involve collaboration, critical thinking, communication, and creativity; life and career skills; and ICT literacy skills (Partnership for 21st Century Learning, 2007). Additionally, they can involve information skills, ethics, social impact (21st Century Skills and Competencies for New Millennium Learners in OECD Countries, 2009), or perspectives that emphasize digital age literacy and inventive thinking (Lemke, 2002). Regardless of the perspective or framework, 21st century skills are relevant because they help students succeed in their curricular activities, their personal lives, and careers. It is often recommended that instructors focus on the development of one skill at a time in the classroom because of the complexity of each skill and the large number of skills. However, digital-based video games are an innovative technological tool that can help students develop more than one 21st century skill.

When playing digital-based video games, players must solve a problem or multiple problems to succeed in the game using skills like collaboration, communication, creativity, and problem solving (Kahila et al., 2020). The specific skill the player will use in the game depends on how the digital-based video game is designed (Hébert & Jenson, 2020). Generally, there are two types of digital-based video games: entertainment-based video games and educational-based video games. In both examples, students can use 21st century skills to solve problems. Therefore, implementation of digital-based video games in the classroom can help teachers meet the needs of curriculum, increase motivation, and develop as well as nurture 21st century skills in their students.

RESEARCH REVIEW

It is important for students to develop 21st century skills because these skills will help them face challenges in learning and life (Ibharim et al., 2019). Development of 21st century skills can also help students become successful members of global society (Saavedra & Opfer, 2012). Ibharim et al. (2019) indicated that because children are part of the youngest generation, they need to be exposed to skills like creativity, collaboration, communication, etc. in education because these skills fall in line with rapid advancements in technology. Similarly, Saavedra and Opfer (2012) recommended that
technology tools are utilized to help support students’ development in 21st century skills as technology provides new ways for them to practice transferring these skills and reflecting on their understanding of these skills (Saavedra & Opfer, 2012). The use of digital-based video games is one technological tool that can improve the development of 21st century skills.

Research shows that video games help improve teaching and learning (Engerman et al., 2019; Mayer, 2019; McLaren et al., 2022). When involving video games in teaching and learning, an individual may interact in a virtual space that is like their daily lives or they may interact in a virtual space unlike anything they experienced (Gee, 2017). Research has also provided evidence that digital-based gaming can help develop 21st century skills (Andersen & Rustad, 2022; El Mawas et al., 2018; Eseryel et al., 2011; Graven & MacKinnon, 2010; Hall et al., 2020; Hsiao et al., 2014; Sánchez & Olivares, 2011; van der Meij et al., 2011; Visser et al., 2013). For example, when playing video games with others, video games have the potential to help students build collaboration skills and collaborative learning skills (Andersen & Rustad, 2022; Sánchez & Olivares, 2011; van der Meij et al., 2011). Video games can also help develop complex problem-solving skills (El Mawas et al., 2018; Eseryel et al., 2011) and students’ creativity skills (Hall et al., 2020; Hsiao et al., 2014). They also provide an environment in which communication skills can be nurtured (Graven & MacKinnon, 2010; Visser et al., 2013). The design of the game may influence specific skill sets, such as using Minecraft to impact creativity. However, the way the teacher uses the game in the classroom is just as important when aiming to develop 21st century skills (Hébert & Jenson, 2020).

**IMPLICATIONS**

While more research is needed to address the relationship between the use of video games and all 21st century skills, there is enough evidence to provide step-by-step instructions specifically for using video games for problem solving, creativity, and collaboration. There are, however, several prerequisites that will help with the implementation process, regardless of the game chosen.

First, teachers need to become familiar with various video games by playing them. While this can be a daunting challenge given the large number of video game titles and platforms (e.g., consoles or mobile phone games), it is important to remember that there are many types of video games out there that appeal to a wide range of audiences. There are puzzle-like games such as Candy Crush, games where you interact with other players online such as World of Warcraft, and games where you build things in the gaming environment like Minecraft. Teachers should not be discouraged exploring and playing games outside of their comfort zone. There are many free games out there to try (see the Appendix). Teachers can also get ideas for games by simply talking to their colleagues, parents, and even students.

Second, it is important for teachers to check with their schools’ technology integration specialists or their schools’ districts regarding the types of technology allowed in the classroom. This will help clarify expectations of the districts’ approved technological tools, as there may be specific digital-based video games that are not approved for use in the classroom and/or need developed safety plans. Third, it is important to consider the ways to assess growth from video game play. There are many ways to assess different 21st century skills, and it is important to become familiar with these assessments. This will help teachers determine if students develop the chosen 21st century skill using video games in the classroom (see the Appendix for suggestions on how to assess different 21st century skills with games).

**Problem solving**

Complex problem-solving tasks involve understanding the problem as well as creating a plan to determine the best solutions (Liu et al., 2011). When incorporating problem solving skills through digital-based video games, the type of tasks in problem solving skills will differ depending on the type of video game. Massive multiplayer online games, simulation-based games, educational games, and video games with an educational game design component, have all been proposed as types of games that can help develop problem solving skills (Eseryel et al., 2011; Liu et al., 2011; Yang, 2012).

One of the most promising approaches in using classroom video games to develop problem solving skills is by playing a video game together as a class and then having large class or small group discussions. These conversations can address both the problems presented in the game and solutions the students identify, create, and implement. To address problem solving skills through digital-based video games, teachers should complete four steps. Any game can be used in these four steps; however, Cheeky Chooks will be used as a demonstration in these steps.
1. Teachers should begin by having the class engage in gameplay on *Cheeky Chooks*.

2. When students begin playing *Cheeky Chooks*, they should determine the goal of the game, which is to build a chicken farm and make profit on the farm, through class discussions (STEAM, 2023).

3. Once the problem is determined, the students can further engage in discussions about ways to make profit through gameplay. The students may draw designs of their farms or make notes about the ways to increase their profits outside of the game.

4. Finally, students will engage in gameplay to determine if their solutions to the problems were sufficient.

Not every teacher will find it useful to implement the game *Cheeky Chooks* (See the Appendix for other suggestions of video games).

Another promising approach that can help develop problem solving skills through video games is by engaging in game design in gameplay to meet lesson objectives. Game design in gameplay involves a digital-based video game where the player designs something in the game, this is commonly known as a sandbox game. To develop problem solving skills through game design in gameplay, teachers should complete three steps. There are many digital-based video games that emphasize students’ designs in gameplay (see Appendix); however, *SimCity*, a city building simulation video game in which players get to build a city of their choice and use their sims in their city, will be used to demonstrate these steps (Electronic Arts Inc., 2023).

1. Before engaging in gameplay, teachers should identify a problem they would like to explore in their class and discuss it with the class. For instance, the problem could address global issues, e.g., poverty, food insecurity, etc.

2. Teachers should encourage students to determine the solution to the problem through the design of a city in *SimCity*.

3. The students should present their city designs to the class, and then the class should discuss if the students’ designs solve the problem presented at the beginning of class.

Both class discussion and game design in gameplay help develop the processes necessary for problem solving in the classroom.

**Creativity**

Creativity is typically associated with the arts; however, it is important to recognize that creativity occurs in day-to-day classroom activities (Glăveanu, 2019). One of the easiest ways to develop creativity in digital-based video games is through game design. Like the development of problem-solving skills, game design in gameplay helps develop creativity. However, the emphasis on the students’ designs in the game should stress newness, originality, and value rather than just solutions to problems (Simonton, 2012). To help students build creativity, teachers should complete four steps. There are many digital-based video games that emphasize students’ designs in gameplay (see Appendix); however, *Minecraft Education*, an educational based video game in which the player is free to roam and interact with the virtual world of the game which consists of blocks and is centered around lessons created by educators around the world, will be used as a demonstration in these steps (Minecraft Education, 2023).

1. Teachers that want to foster creativity skills in *Minecraft Education* should begin by explaining to students the dimensions of creativity and the lesson’s objectives. They should also introduce the *Minecraft Education* environment to their students by using their own created lessons or lessons offered in the platform in *Minecraft Education*’s lesson gallery.

2. Teachers will need to explain the tools in the game that will help students in the design process and provide time for students to become familiar with the video game.

3. Students then can navigate the lesson in *Minecraft Education* and engage in design.

4. To ensure that their students develop creativity, teachers, peers, and/or the student themselves should evaluate students’ designs at the end of the lesson based on newness, originality, and value (Simonton, 2012).
Minecraft Education can be used for a variety of curricular subjects to help develop creativity skills. However, when developing creativity through game design in gameplay, teachers should choose the digital-based video game that best suits their classes’ needs.

Another approach to game design that nurtures creativity is when students design their own video game. Game design involves the process of developing and producing a video game for entertainment and/or educational purposes (Steffyn, 2019). To help students develop creativity in this way, teachers will need to complete four steps. There are many examples of game design programs (see Appendix); however Scratch, a free coding program that provides opportunities for students to design video games through visuals and block-based designs, will be used as an example of a game design program teachers may implement in this step-by-step process (Scratch Foundation, 2022).

1. Teachers should introduce the dimensions of creativity to their students.
2. Teachers will need to provide time for their students to become familiar with Scratch. Scratch provides tutorials for students to learn how to use the program.
3. Once students are familiar with the game design program, they can design their own video game.
4. Finally, the designed games will be evaluated by the teacher or students regarding elements of newness, originality, and value (Simonton, 2012).

Whether designing the game or designing in gameplay, both step-by-step instructions help emphasize how digital-based video games can develop creativity for students.

Collaboration

Collaboration in digital gameplay involves two or more players working together to solve tasks in games (Ruipérez-Valiente & Kim, 2020). There are many gaming environments that support the development of collaboration skills. For example, collaboration can be supported through playing a co-op game. A co-op game is a cooperative game where players work together to solve the game (IGN Staff, 2021). When implementing co-op games that help develop collaboration skills in the classroom, teachers should complete two steps. There are many examples of co-op games (see Appendix); however, It Takes Two, a co-op action-adventure platform video game in which players must work together through puzzle-based challenges to save the two main characters, will be used as an example in the step-by-step process (Ogilvie, 2022).

1. Teachers should begin by choosing students to work in teams of two emphasizing that they need to interact with each other in and outside of gameplay.
2. Once the students have achieved the goal of gameplay, the teacher should discuss with the class the benefits of collaboration and how it occurred inside and outside the game.

The design of It Takes Two focuses on the importance of collaboration as players will only be able to engage in gameplay on It Takes Two if there are two players, however not all games are designed in this way.

Research has also shown that collaboration can occur when two individuals play together in a single player game (Ruipérez-Valiente & Kim, 2020). To develop collaboration skills in a single player game, teachers should do four things. Any single player game can be used (see Appendix), however Shadowspect, a puzzle-based game that assesses geometry and spatial reasoning through puzzles provided in the game, will be utilized as an example in these steps (MIT STEP Lab, n.d.).

1. Teachers should encourage engagement in collaborative gameplay by having students work together in teams of two.
2. Teachers should also emphasize specific times in which students are playing or observing Shadowspect.
3. Teachers should encourage discussions of solutions while gameplay is occurring as well.
4. Finally, teachers should discuss how collaboration impacts the solving of puzzles after the gameplay has ended.

Sometimes the design of the game will impact students’ 21st skill development, such as video games that feature co-op environments, video games that feature design in the gameplay, etc. It is important for teachers to acknowledge
this when thinking about fostering 21st century skills through digital-based video games. However, it is also important to remember that there are many digital-based video games available to fulfill different educational contexts. Teachers should also remember that sometimes the choice of game does not matter and the development of 21st century skills with digital-based video games relies on scaffolding and teacher/peer interaction. Once teachers make the decision to implement digital-based video games in their classrooms, they will find not only that their students are able to develop these 21st century skills but that their students are better equipped for their futures, all because of implementation of digital-based video games in the classroom.

REFERENCES


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Ogilvie, T. (2022, November 3). It takes two review. IGN. https://www.ign.com/articles/it-takes-two-review
Stefyn, N. (2019, October 13). What is game design and how to become a game designer. CG Spectrum. https://www.cgspectrum.com/blog/what-is-game-design
APPENDIX

Video games discussed in implications (*=free game)

Problem solving skills
- Cheeky Chooks* (sandbox/strategy game): https://store.steampowered.com/app/922460/Cheeky_Chooks
- SimCity (building simulation game): https://www.ea.com/games/simcity

Creativity skills
- Minecraft Education (sandbox game): https://education.minecraft.net/en-us
  - Lesson in Minecraft Education: https://education.minecraft.net/en-us/lessons/shipwreck-narrative
- Scratch* (game design program): https://scratch.mit.edu/
  - Scratch tutorials:

Collaboration skills
- It Takes Two (action-adventure platform co-op game): https://www.ea.com/games/it-takes-two
- Shadowspect* (puzzle-based geometry spatial reasoning game): https://fielddaylab.wisc.edu/play/shadowspect

Additional suggestions of video games (*=free game)

Problem solving skills
- Big Brain Academy (puzzle game): https://bigbrainacademy.nintendo.com/go-solo/
- Candy Crush* (puzzle game): https://www.king.com/game/candycrush
- Stray (adventure game): https://stray.game/

Creativity skills
- Game Maker* (game design program): https://gamemaker.io/en
- Gamestar Mechanic* (online game focusing on game design): https://gamestarmechanic.com/
- Minecraft (sandbox game): https://www.minecraft.net/en-us
  - Minecraft Classic* (sandbox game): https://classic.minecraft.net/?join=zeYcR0Oaz8P3Ss1t

Collaboration skills
- Fortnite (competitive massive multiplayer online game (MMOG)): https://store.epicgames.com/en-US/p/fortnite
- World of Warcraft (massive multiplayer online role-playing game (MMORPG)): https://worldofwarcraft.blizzard.com/en-us/

Reading recommendations for 21st century skills assessments

*See the reference list for research regarding gaming and the development of 21st century skills.
The digital-based video game, *Minecraft*, is a vital tool used in the classroom to support student learning. It has not only been proven to benefit learning as well as to help develop soft and hard skills, but it has been shown to intrinsically motivate students simply because playing video games is fun and engaging. Students also have the opportunity to learn and engage in a variety of curricular subjects through the educational version of this video game, *Minecraft Education*. Students take charge of their learning when engaging in *Minecraft*. Their familiarity with digital tools used in video games makes it easy for them to engage in the lessons and help their peers. Students can also develop design thinking using *Minecraft* through designing, testing, and modifying their own creations in the game. The goal of this chapter is to provide directions on onboarding *Minecraft Education* and practical examples of how to integrate *Minecraft* through real life implementations.

*Keywords*: Minecraft; Minecraft Education; K–12 education; digital tools; video games

**INTRODUCTION**

It is no secret that digital-based video games are a chosen pastime of countless students. Many children will leave school, hop on the bus, play a game on their phone, get home, grab a snack, and then head to their gaming counsel to pick up where they left off. The passion for video games is there for students because video games are engaging for students, they help develop creativity skills, and they are fun (Engerman et al., 2019; Phillips & Popović, 2012).

Digital-based video games have also been utilized successfully in teaching and learning. When incorporating video games in the classroom, students are able to build confidence in themselves and in the tools they are utilizing (Ball et al., 2020). Teachers are able to develop motivation in their students because the games are fun and provide challenges in the classroom. Teachers are also able to address multiple curricular subjects through educational based video games which helps them meet learning objectives. With this information, educators need a platform that is both gamified and meets the engagement, creative, and entertainment needs of students.

**Enter Minecraft Education.**

*Minecraft Education* is a digital-based educational video game and is a version of the popular entertainment video game, *Minecraft*. The gaming environment functions like a sandbox game, or a game in which players are free to roam and interact with the gaming environment (Jessey & Alston, 2023). However, the gaming environment stresses learning; and learning occurs in *Minecraft Education* because the teachers are able to create their own lesson plans in the game or follow pre-built lesson plans offered in the game by other educators and creators. Through *Minecraft Education*, students engage in a multitude of curricular subjects including mathematics, language arts, art and design, computer science, etc. This digital-based video game functions very similarly to *Minecraft*, which means that the engagement, creative outlet, and fun aspect of video games, can be developed in the classroom. In this chapter, educators will learn about digital-based educational video games like *Minecraft Education*, and how to integrate these tools into K–12 curriculum.
REVIEW OF RESEARCH

Digital-based video games benefit students in their motivation, learning, and development of 21st century skills (Ball et al., 2020; Engerman et al., 2019; Phillips & Popović, 2012). When using digital-based video games in the classroom, students build desire to continue their studies because of the different ways they approach challenges in the classroom (Phillips & Popović, 2012). Students are also able to build computer self-efficacy through computer gaming which helps them develop positive attitudes towards STEM (Ball et al., 2020). Entertainment based video games in particular help increase students’ creativity, critical thinking, communication, and collaboration skills (Engerman et al., 2019). The digital-based video game Minecraft and its educational adjacent version Minecraft Education, have also been found to benefit students’ learning in a variety of contexts (Baek et al., 2020; Bile, 2022; Hewett et al., 2020; Pusey & Pusey, 2015).

Minecraft Education has been used for multiple curricula including science, math, social science, language arts, computer science, etc. (Baek et al., 2020). When students engage in Minecraft Education, they are more likely to complete tasks because interacting in the game motivates them to keep working (Pusey & Pusey, 2015). Engagement in Minecraft can also trigger social skills in teamwork, and it can do so when students have the opportunity to interact with one another in the game (Hewett et al., 2020). Minecraft Education has also been found to help students solve abstract and complex scientific concepts because students are able to form new ideas about knowledge developed in the game (Bile, 2022). Finally, incorporating gameplay in Minecraft has been found to help students develop innovative designer skills which helps nurture creativity (Hewett et al., 2020).

IMPLICATIONS

According to the Minecraft Education (2023) website, “Minecraft Education is a game-based platform that inspires creative, inclusive learning through play.” This description may immediately remind readers of the students who make gaming a priority in their day. These are the students who crave a creative outlet to show their understanding that may go beyond pen, paper, and a slide deck. These are the students who have a skillset that they are so eager to apply in the classroom, but rarely get to show off. This description also reminds readers of those students who have never had the chance to use tools like Minecraft Education but may flourish when the opportunity arises. Classroom integration of a tool like Minecraft Education can open closed doors for students, and open closed eyes for educators. There are a few steps that need to be taken when implementing digital-based video games like Minecraft Education in the classroom.

The first step is playing. Educators should become familiar with the digital-based video game/s they are thinking about integrating into their classroom. They should take some time and get to know what these video games have to offer. Play to explore the positives and play to experience possible roadblocks. A great place to start is with a free version of a tool like Minecraft Classic (see Appendix). After educators have played, they should share their experiences with their students. This is a great opportunity to introduce video games as a learning tool and to brainstorm possible ways, as a teacher and student team, of integrating these platforms into the classroom.

The second step is to talk. Set a time as a team of teachers, administrators, and technology department members to meet, and allow all parties to ask questions, voice concerns, and share input. Potential conversation starters are as follows:

- What do you hope to accomplish using Minecraft Education?
- Will Minecraft Education be used as an assessment piece?
- Will Minecraft Education be used as an educational tool?
- What about the students that just play and not work?
- Will this integration align to standards and lesson objectives?
- Can we afford licensing?
- Does it make sense to start with the free trial?
- Is this tool safe?
- Do we have the devices to support Minecraft Education?
- Do we need to create accounts?
While talking is the second step, it should never end, as it is crucial to keep communication open as lessons modify, usage increases, and budgets change. These questions can involve other digital-based video games as well, such as Roblox Education, which is the educational adjacent version of the game Roblox. Roblox is a gaming platform that stresses creating and sharing with others (Yaden, 2020). It functions similar to Minecraft; however, the design of the game involves a mix of Minecraft and Lego (Peru, 2020). Minecraft Classic is another example of a digital-based video game that could be included in these conversations. This is the free entertainment version of Minecraft. It functions very similarly to Minecraft Education; however, it does not have an educational component built into the platform.

The third step is onboarding. Like many digital tools, Minecraft Education requires paid licensing that can be purchased by anyone with a Microsoft 365 account. For most educational institutions, free Microsoft 365 accounts can be created for students and staff (see Appendix).

There are multiple ways to purchase Microsoft Education licensing. Both volume and direct user licenses can be purchased. It is important to include this in your team conversations to decide which route is best for your district. And, if your district wants to test the water before jumping in the purchasing pond, a free trial (see Appendix) is available for users with a Microsoft 365 account! The free trial allows teachers to log in to Minecraft Education up to 25 times and students up to 10 times. It is important to acknowledge too that there are similar digital tools that do not require paid licensing, like Minecraft Classic. Consider your options when it comes to implementing Minecraft Education or a similar digital-based video game, but always keep in mind your school’s guidelines, policies, and age requirements when integrating any tool into a classroom, especially one that is not designed specifically for educational purposes. It is recommended to get approval from district administration before implementing any tool.

The fourth step is to give access to students. Digital-based video games, like Minecraft Education, can be added to desktop devices such as a PC or Mac, and individual devices like Chromebooks and iPads. Different districts approach this in different ways. Some districts add the Minecraft Education app to all student devices for access at any time. Some districts have specific devices that are moved from classroom to classroom when Minecraft Education is being used to limit access. Some districts add the app onto student devices, and then remove it when the lesson is done. Whatever route your district chooses to take, it is important to talk about proper usage with students and discuss when it is okay (and not okay) to use Minecraft Education, or similar digital-based video games.

Now, let the learning (and fun) begin with step five, classroom integration. The integration process is different for all educators. Some teachers create a vision and are able to use what they know to give students directives and guidance. Other teachers have a standard they want to work with but have no idea what to do next. A great starting place for all teachers planning the integration process is the digital-based video games’ resource page. For example, in Minecraft Education’s platform, teachers can enroll in the Minecraft Education: Teacher Academy (see Appendix) which is a learning path of modules that teachers can complete to better understand how to use Minecraft Education as an educational tool. Additionally, on the Minecraft Education resource page (see Appendix), teachers will find many valuable resources like lessons that can be filtered by subject area and grade level and build challenges to get their students’ interests sparked! Other digital-based video games, like Roblox Education, also provide educator resources which is a place where featured lesson plans and tutorials are available. See the Appendix for information on the lesson plans offered on Minecraft Education and other gaming platforms.

When teachers are ready to launch a digital-based video game, like Minecraft Education, that emphasizes creativity in their classroom, it is important to introduce it as an educational tool and to guide students through the setup process. Creating a slideshow presentation (see Appendix) provides setup directions and shortcuts that are helpful to students. Teachers can then add this slideshow presentation to their project directions (and display it on their display boards in their classroom), for students to reference throughout their build.

Diversifying usage is the final step. It is easy to get in the habit of using a tool for a sole purpose, but digital-based video games like Minecraft Education can be used in a multitude of ways. For example, when diversifying usage with Minecraft Education, a single district can use Minecraft Education in elementary, middle, and high school settings, all for different outcomes. Fourth graders can create ecosystems with different landforms and features. They can visit these ecosystems throughout the year to add invasive species, or create natural disasters, and see the impact these different changes make. Seventh graders can create fully functioning Roman aqueducts in the fall and the Great Mosque of Djenné later in the spring. Fifth graders can practice plotting points on a graph through world building, and high school students can practice coding skills.

Digital-based video games, like Minecraft Education, have also been proven to be a great addition to students working on design thinking projects and building problem solving skills with their design projects (Hewett et al., 2020; The
Many students have used these tools in the prototyping phase to generate models or replicas of their final creation/s. Using *Minecraft Education* allows the students to design, test, and modify prototypes, as well as collaborate to join design forces.

Using digital-based video games for educational purposes does not need to be limited to a school building. Many students are already using digital-based video games, like *Minecraft and Roblox*, on their own gaming platforms at home after school in their own time. Consider incorporating at home use with these games as an optional way for students to show understanding of a lesson. Educators have found students to be very excited to tell parents that they’re going down in the basement to play *Minecraft* because their teacher said it was okay.

- Let students show their understanding of geometric shapes by building a world full of them.
- Let students show their understanding of ancient civilizations through the building of one that is fully functioning.
- Let students show their understanding of SEL, social emotional learning, through creating a digital community that depends on each other.

Using digital-based video games, like *Minecraft*, in the classroom not only supports instructional design, but best serves our students so they can acknowledge that learning can be engaging, creative, and fun.

**REFERENCES**


APPENDIX

For the resources and recommendations below, be sure to talk to your district administrator/s and follow district safety and usage guidelines.

**Microsoft 365 Resource**
- Microsoft 365 Account Setup
- Microsoft 365 Video Training

**Minecraft Education Resources**
- Minecraft Education System Requirements
- Purchasing Minecraft Education
- Minecraft Education Free Trial
- Minecraft Education Resource Page
- Minecraft : Teacher Academy
- Minecraft Education Lessons
- Minecraft Education Build Challenges
- Minecraft Education Blog
- Minecraft Setup and Shortcuts Example

**Extra Sandbox Games**
- Roblox (free)
- Roblox Education
- Minecraft Classic (free)
Augmented Reality: Expanding Our Pedagogical Toolbox to Teach Elementary Science Topics

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The use of augmented reality (AR) technology in the elementary classroom is a pedagogical approach that builds on models of technology integration and inquiry-based teaching practices. AR is a way to combine both the virtual and physical environment; therefore, it can serve as a great tool when teaching science topics. Presenting learners with visually engaging 3D models can help students feel less overwhelmed by complex concepts. This chapter shares details on how elementary pre-service teachers used AR to teach biology and astronomy topics and expand their pedagogical toolbox. Our teachers also identified three themes related to their use of AR: (a) an affinity to using iPads to complement instruction, (b) enhanced comfort with cross-content integration, and (c) interactive engagement with science content. This chapter informs elementary teachers on how to leverage this immersive technology in their classrooms to increase student engagement and use technology to complement their teaching of science topics.

INTRODUCTION

Childhood is a fertile period for seeding and nurturing an interest in science-related subjects (Weyer, 2019). However, persistently low scores in STEM (Science, Technology, Engineering, and Mathematics) proficiency among United States children is a source of grave concern (National Science Foundation, 2022), since elementary grades are the building blocks of our public educational system. High-quality professional development experiences in science/STEM are therefore sorely needed in order to prepare teachers to address this acute need and meet the needs of digital-age learners (Asim et al., 2022).

This chapter draws attention to educational uses of augmented reality (AR) that can be applied within elementary science instruction. We know that students who use immersive technology to learn science are more engaged and motivated because science feels more relevant in their lives (Brown et al., 2021), and AR is perhaps the most high-profile example today of immersive technology that can be used to support science learning. AR is a way to combine both the virtual and physical environment; therefore, it can serve as a great tool when teaching science topics. The AR interface allows active engagement of the learner to manipulate the images and the interaction with content, allowing for longer periods of sustained engagement. Presenting learners with visually engaging 3D models can help students feel less overwhelmed by complex concepts. Our work below explores how teachers were engaged in the implementation and use of AR in elementary science education, and we provide recommendations for how other elementary teachers can engage their students in similar learning experiences.

RESEARCH REVIEW

In elementary science lessons, teachers must exercise the skills to plan, adapt, and enact lessons that will engage their students in rich interactions. AR is an immersive technology with enormous potential to support student learning by increasing the length of attention (Raghw et al., 2018), adding motivation, and scaffolding (Yoon et al., 2017). AR
can energize elementary teachers by expanding their pedagogical content knowledge (PCK), use of research-based teaching practices, and having the confidence to innovate with their teaching (Bruewer et al., 2018). Because AR enriches the user’s perception of the real-world environment with additional virtual computer-generated imagery (Chen & Tsia, 2012; Crews, 2018; Ibañez & Delgoda-Koos, 2018), it is especially effective in connecting students to the abstract, difficult-to-visualize objects, events, and phenomena that lie at the heart of science: the inside of the human body, the shift of tectonic plates, even the formation of chemical bonds (Ozdamli & Karagozlu, 2018). Although AR is not a hands-on learning activity in the literal sense, it enriches the teaching and acquisition of scientific concepts and methods (Walczak et al., 2006) in ways that position the teacher as the facilitator of inquiry. AR thereby acts as a catalyst for unleashing the creativity of elementary teachers in a “compelling and visually stimulating” way (Crews, 2018), generating opportunities for imaginative activities, student-centered learning, 3D models, and inquiry-based projects (Wang et al., 2013).

Implications

The primary goal of this chapter is to share ways to infuse AR in elementary science instruction since it builds on research implications from a science methods course with field placements in elementary classrooms. Specifically, we consider two use cases of AR: (a) the GoogleAR search engine platform in the context of learning biology, and (b) three iPad apps: Multiverse, Wonderscope and AugmentifyIT in the context of learning astronomy. Below, we describe these two use cases in detail and what we learned from our pre-service teachers regarding their use of AR for elementary science learning.

Teaching Biology Topics using GoogleAR

GoogleAR can be easily manipulated using the Google search engine. The first time the teacher candidates are introduced to AR, we use a fun example, such as googling “PAC-MAN” since one of the best ways of teaching in an inquiry-based practice is ABC (activity before content; e.g., Cavanagh, 2007). The image below shows what the screen would look like in a Google search.

Figure 1

Screenshot from Google

Search “PAC-MAN” in the Google Search bar

From PAC-MAN
See PAC-MAN in your space
View in 3D

Next, the students are given directions to explore several other science concepts from as simple as looking for animals to complex topics such as ionic bonds. Below are the steps shared on a slide deck:
Create an experience for your students related to a science concept you will be teaching in your schools through your iPads.

Here is how you can have such a 3D hologram in your ‘surroundings’:

**Step 1:** Search for a species, such as ‘Tiger’
**Step 2:** On the 3D module that appears, click on ‘View In 3D’:
**Step 3:** Click on ‘View in your space’
**Step 4:** Show your phone ‘the ground’; follow the instructions on your device

Below are four images in a photo collage that were captured during the free exploration time. Several science concepts can be explored using this free educational technology, such as celestial bodies like Mars, Europa, and the Earth’s moon. Concepts related to biology such as red blood cells, skeleton, brain, and whole systems like the nervous system or as small as the flagellum or plasmids. The list goes on to include more abstract concepts in chemistry such as chemical bonds, ionic bonds, covalent bonds, or even chemical compounds like ethene and propanol. You can even make it fun and look up some of your favorite pets (e.g., cat, dog, duck), forest animals (e.g., snake, turtle, wolf), marine animals (e.g., shark, turtle, penguin) or prehistoric creatures (e.g., Brachiosaurus, Tyrannosaurus Rex, Velociraptor, Triceratops); these can hook students to talk about biomes, food chains, physical features and discuss the importance of documenting and STEM careers such as field biologist and archaeologists. The GoogleAR list is constantly growing each year.

**Figure 2**

*Free exploration with GoogleAR: Plant cell, ionic bond, skeleton, shark.*

Depending on the clinical placements in the partnering elementary schools, the teachers can choose to use AR (if appropriate) to the standards and learning outcomes. Sometimes, our teachers are asked to teach science in the literacy block, so exposure to several platforms helps them to best design lessons to be implemented in schools.
**Teaching Astronomy Topics Using AR Mobile Apps**

Many children may be familiar with entertainment-focused mobile apps that use AR (such as Pokémon Go or Snap-chat). Our teachers used several educational mobile apps on the iPad® (including Curiscope Multiverse, Wonderscope, and AugmentifyIt) in order to teach astronomy topics. A summary of these apps and the science concepts that they support are listed below in Table 1.

**Table 1**

*Augmented Reality Apps Used in Elementary Science Methods*

<table>
<thead>
<tr>
<th>Name</th>
<th>AR app</th>
<th>Science Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curiscope Multiverse</td>
<td><img src="image" alt="Multiverse" /></td>
<td>Planet Earth, Planet Mars, and the Moon and its features</td>
</tr>
<tr>
<td>Wonderscope</td>
<td><img src="image" alt="Wonderscope" /></td>
<td>Birth of a star in a galaxy</td>
</tr>
<tr>
<td>AugmentifyIt</td>
<td><img src="image" alt="AugmentifyIt" /></td>
<td>Topic includes many celestial bodies like the planets, moon, asteroid belt, etc</td>
</tr>
</tbody>
</table>

When introducing the relevant standards related to teaching Earth and Space concepts, many of our teachers stumble on how to present concepts beyond the most popular activity of using Oreo® cookies and the moon phases. Allowing the educators to first dive into exploring the Multiverse® posters, Earth, Moon and Mars, in the classrooms gives them the opportunity to have a planet like Planet Earth come off the poster and be in a 3-dimensional form. Our teachers first learn about the major layers: inner core, outer core, mantle and crust. The application on the iPad® not only assists in the visualization of different layers but there is also a narration that describes these layers for the learner (see Figure 3 below). The capability to physically walk around a now floating celestial body helps individuals to gain a better understanding of the major components. While the learning is engaged with the content, they can be documenting what they learned on a graphic organizer prepared beforehand.
Next, the pre-service teachers learn about Wonderscope®, which is an interactive story-telling app. During their exploration with this app, the learner has to not only interact with the iPad® screen like in most applications, but also talk/read the screen in order to progress in their learning. This application is extremely well-designed with imagery and characters that keep the learner engaged in moving along the story while they learn about how a star comes to life. The learner also needs to be able to walk around with the iPad® which keeps the individual highly engaged through the interaction with the story plot (Figure 4). Like in many cases, the teacher may opt to front-load the lesson with academic vocabulary.

**Figure 5**

*Images using the Wonderscope App with the words on the screen that need to be read by the learner*
Another interactive app that caters to grades K–5 is AugmentifyIt®. This app uses the AR markers on playing card sized cards. The deck of cards has three specific topics that are covered: oceans, elements, and space. When using the *Space* deck of cards, the learner uses the iPad® and the image of the card lifts off the card in a three-dimensional shape. Each individual card has one celestial object (e.g., Sun, Earth, Black Matter) on the front and a short description about the object on the back. The learner can place the cards and take a tour of the galaxy by sitting in their seats with the cards placed on their desk. One of the features that educators may particularly like is the formative quizzes on each card. While reading about the facts about each object in space, the learner can also take the short quiz to check for understanding.

**Figure 6**
*Using the AugmentifyIt cards*

**Figure 7**
*Using the AugmentifyIt cards*

**Reflections on AR from Pre-service Teachers**

We collected feedback from our teachers who participated in these AR-infused activities and asked them to reflect on the impact of exploring and using AR apps for the teaching of science/STEM content. Below, we share a few major themes from their feedback related to lesson plan design and science instructional practices. The themes are as follows: (a) an affinity to using iPads® to complement instruction, (b) enhanced comfort with cross-content integration, and (c) interactive engagement with science content.
Table 2

Sample Pre-Post Drawing

<table>
<thead>
<tr>
<th>Pre-Drawing (First Day of Class)</th>
<th>Post-Drawing (Part of Final Exam)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Pre-Drawing Image]</td>
<td>![Post-Drawing Image]</td>
</tr>
</tbody>
</table>

The Affinity of Using AR for Instruction

Initially, several of our teachers at the start of the semester were hesitant to teach science and use edtech as indicated in their Week 1 reflections: “My biggest fear as an educator is that I will not incorporate enough science into my classroom...[Tammy]” However, several teachers appreciated and valued the free exploration time in class with the iPads®: “Something that I took away and really enjoyed...placing your [iPad] camera and being able to see the amount of things, it’s amazing! Technology in the classroom can be really cool. [Mary]” Several teachers also mentioned the benefits of using educational apps to complement teaching science topics as well as how edtech informed their teaching: “I would use this technology to give students a hands-on experience with materials in the elementary grade-levels and in different subjects...these tools are great for all teachers because most teachers do not use technology enough to keep the students intrigued. [David]”

Most of our teachers did not even have educational technology in their pre-drawings and/or narratives. Some teachers mentioned they worried about steep learning curves being a barrier to the use of AR technology in reflections. However, their post-reflections revealed that prolonged time to explore various apps on the iPad® related to STEM concepts in class with the instructor troubleshooting allowed participants to ease their worries. Overall, our teachers were more comfortable with the use of AR and shared their ideas to embed in their 5E lesson and/or in another cross-curricular lesson.

Enhanced Comfort with Cross-content Integration

Many of our teachers also mentioned a deeper understanding of science content as a result of being able to engage with 3D images. The learning was also facilitated by written documentation on graphic organizers, video recording, or quick embedded formative assessments within apps. Our teachers share this sentiment in both their reflections and their Flipgrid video recordings. Not only did they use AR in science teaching, but they also used educational technology such as iPads in other content area teaching:

I used a website for augmented reality which had a photo trigger that [is] used with the Avara app which you download on any iOS or Android device, once you download it you play the game that helps the polar bear explore their habitat...The game actually helps you understand about human waste and global warming. I was excited to learn about this tool that is about animal adaptations...and this tool allows people to connect and realize that their [sic] are other countries and places, which is a connection to geography. [Katy, Flipgrid Video Reflection Recording]

Another teacher suggested:

AR is interactive and can get kids out of their seats, since sitting down all day can get boring. The app that I used is Catchy, it’s an AR app that is immersive and you use it without touching the screen and you use the device itself and actually pop a bubble and it explodes. You use your device [to] collect the letters to place in boxes and create words. The kids can use this to help them remember how to spell them. [Cathy]
This response indicates that this teacher is not only applying educational technology in their science instructional practice, but also carrying it over to another content area (in this case, English Language Arts). Overall, our teachers found value in using the educational apps model and discovered new apps that aligned with other content areas they were teaching in their clinical placements.

Interactive Engagement with Content

Additionally, our teachers enjoyed the interactions that were afforded by the apps on iPads. Several teachers mentioned the videos, narrations, and enhanced images as factors that helped them learn science content: “The last strategy I would use is integrated technology in my classroom positively and educationally...[AR helps in] sparking this natural curiosity and allowing them to explore. [Tammy]” Similarly, Ranita shared: “Getting students actively engaged in learning since students today grow up using technology...AR gives them the opportunity to create their own content [stories].”

Our teachers realized that learning through the use of an iPad® and an app could assist students in their classrooms and provide immersive experiences that can capture and hold learners’ attention due to the multi-modal aspect of AR learners having fun while being more immersed and engaged with the content due to the visual stimulation.

Suggestions for Implementation

How many of our students can go home and say that they walked around the surface of the moon today? Or explored the microvilli lining of our large intestines in our GI system using an iPad®? Or say guess what there was a giant panda eating bamboo on my desk today and I made a sketch of it then learned about their habitat all using the iPad®. There are several websites and apps that can be utilized by teachers that can transform their teaching practice. AR is an educational tool that is not normally used in our elementary classrooms and can allow our students to explore concepts in-depth as well as cross-curricularly. It can be a valuable tool since it allows students opportunities that may not be possible without this tool - in one example, students can explore plant cells and dive deeper to identify the different organelles and their functions (Asim et al., 2022). In another instance, AR allows the students to explore objects in outer space that are otherwise inaccessible to them. AR makes the invisible visible, and the interactivity between the learner and AR content allows learners to have more control and tailor to individual needs. To get started in our classroom all you would need is a smartphone or a device such as the iPad®. Teachers often have limited resources and immersive learning through AR tools can allow for authentic experiences in numerous ways. Before getting started this is a little research and homework that needs to be done by teachers like securing funding for devices for 1:1 experiences and having the proper network requirements, and having the support of building administration and informational technology services. When working with different apps a teacher also has to consider space and lighting in their classroom; therefore, you have to explore platforms and tinker with apps as a teacher before sending students on their way to freely explore with AR.

We encourage educators across the board to explore AR technology to complement teaching abstract concepts and hard to visualize concepts. One book that we recommend is written by Jaime Donnally called Learning Transported. There are also a few other cross curricular app that one can try; like Photomath (https://photomath.com/en) which allows students to scan math problems and the app can walk the student through a solution. 360Cities (https://www.360cities.net/) can be downloaded to access information about places around the globe. Tyker (https://www.tynker.com) is a tool that can be used for coding. Night sky app helps the viewing of constellations. AR isn’t just a tool to use in the classroom, it can be used if you’re in a foreign country and need to translate a sign, just use the Google Translate app. Since there are several free resources there is no reason to delay exploring resources that may enhance instructional practice and immersive experience for our elementary students in the digital age.

ACKNOWLEDGEMENT

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REFERENCES


Exploring Student Creation of Virtual Reality Utilizing 360 Video

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Virtual reality (VR) has grown in popularity in the classroom, but teachers struggle to implement it because finding age-appropriate content that relates to the curriculum can be difficult. A solution to this issue is to create VR that does fit the curriculum. Generally, creating VR is difficult as it requires programming experience and specialized software. However, 360 video can be used instead to offer an immersive experience without additional technical knowledge. Student-created videos also provide numerous benefits such as increased motivation, engagement, and expanded learning, and the added immersive experience of 360 videos leads to improvements in spatial reasoning. This chapter explores implementing the creation of VR with students using 360 video and offers implications and tips for those who would want to try something similar.

INTRODUCTION

Virtual reality (VR) has grown in popularity of its use in education over the past several years. VR can be defined as using a computer to create an interactive immersive experience from some sort of head mounted display or desktop where the user can feel part of the virtual or simulated environment (Cochrane, 2016). It has been used to take students on field trips, teach students about places they normally could not travel (e.g., outer space), and has even helped students with disabilities. See Appendix A for a reading list of research in VR.

However, many teachers struggle with finding relevant content and with conceptualizing the type of content they can offer with VR (Baumgartner, 2020). One solution to that issue is having students create their own VR. While there are several uses of pre-existing applications of VR, there are limited resources to help students create it. Many shy away from VR creation as many software systems such as Unity require programming skills or advanced technical skills (i.e., Jerald et al., 2014; Youngblut, 1998). However, the promise of 360 videos allows anyone to easily create VR without any coding. This chapter proposes an alternative way for students to create VR by using 360 videos and explains lessons learned from a study that was conducted with elementary students.

RESEARCH REVIEW

VR can be beneficial in the classroom as it has been shown to hold attention for lengthy periods and to improve motivation for learning (Chiang et al., 2014; Pantelidis, 2010). Teachers often have a hard time finding content that fits their curriculum and one solution is to create their own. 360 cameras offer the ability to create VR without expensive software and coding skills (Feurstein, 2018).

360 video is an educational technology tool that has been used in the classroom and for other purposes such as teacher education (Ferdig & Kosko, 2020; Kosko et al., 2021; Zolfaghari et al., 2020) as well as for student creation (Baumgartner et al., 2022; Evens et al., 2022). It involves taking a video in an omnidirectional form using a special camera that allows users to look into any direction while viewing (Snelson & Hsu, 2019). It often uses software to stitch the two images together; however, YouTube and other video programs have made the process of stitching much easier.

Video creation has been proven to lead to academic benefits such as expanded learning, increased engagement, and critical thinking skills (Morgan, 2013). 360 videos can offer a richer experience than traditional videos because of the immersion and presence that it offers (Bonner & Lege, 2018; Martín-Gutiérrez, 2017). According to Feurstein, (2018, p. 2), “with 360-degree cameras, content creation for VR can be accelerated. It offers new features to communicate and view content.”
A previous study conducted explored the impact of spatial reasoning skills of third and fourth grade students after consuming and producing VR using 360 video. The results showed improvements in spatial orientation and mental rotation and promise of student-created VR using 360 video (Baumgartner et al., 2022).

IMPLICATIONS

Working with new technologies may seem daunting, but there are many helpful resources that are available to aid in the process. This section will describe five steps that can be taken to start using VR and 360 in the classroom and helpful tips of lessons learned from previous implementations with younger learners.

Step 1: Find suitable equipment and try it out yourself

Whether you are planning on using both VR headsets or just 360, you will need 360 cameras to start. In Appendix B, there is a list of brands that have quality 360 cameras and VR headsets. Please note that a VR headset is unnecessary to view 360 videos, as they can be viewed on a smartphone or iPad. However, having a VR headset can help with the sense of immersion that VR gives (but again, it is not necessary to have a headset to be able to view videos). The Ricoh Theta V is a reputable brand of 360 video cameras. Theta has an app that connects to a smartphone or iPad for easy upload of videos to YouTube. Insta360 is another quality brand that requires their own software for upload (see https://bit.ly/3GCiBdT for a short video on how to upload).

Watch some 360 videos on YouTube to start (whether that be on a Smartphone or a VR headset). See Appendix C for some ideas. This will help to familiarize yourself with how a 360 video looks to the end user. Then try recording some of your own videos and uploading them to YouTube. At this point, it may also be wise to make content-related videos to give students ideas for their own videos later.

For the students later on, it is helpful to create a ‘classroom account’ on YouTube that is already logged in on all of the student iPads for easy upload prior to them recording their videos. If iPads are not obtainable, videos can be uploaded via smartphone or a computer, depending on the brand. This can be done in this first step in order to be prepared for the next steps.

Step 2: Find content that fits the curriculum.

VR and 360 can fit into any type of curriculum that involves something hands-on and involves something a student could take a video of. The app Wonders of the World is a good app to help familiarize students with VR headsets. This does not necessarily need to be content-related, but it is helpful if it is. If the Oculus (Meta) brand is used, apps are located here: oculus.com/experiences/quest/ (many of the apps are free). For example, if the students are learning about space in their curriculum, a general ‘space’ keyword can be used to find an app that would relate (Titans of Space is a quality app for space-related learning). Use generic keywords to find what you are looking for. The goal is to find engaging and exciting apps that also fit in with the curriculum.

The Oculus brand of headset is very user friendly, but try out the headset and apps that are chosen ahead of time. Students sometimes struggle with navigation, and it helps as an instructor to have seen it before. It is an opportunity to test whether the app fits the curriculum and the age level of the students. If there is time, make tutorials or guides for students to follow when using the equipment. This can help students to troubleshoot on their own (and sometimes, it is hard when you have a big class size and only one teacher!) This can also help with critical thinking and problem-solving skills. See Appendix B for an example guide for the Ricoh Theta V camera.

Step 3: Have students explore VR (or 360)

When introducing students to VR, it is a good idea to have them remain sitting, and to tell them to raise their hands if they have issues and keep the headset in the box to minimize the chance of dropping it. They may bring up concerns or
questions on how to navigate to a certain spot or how to restart an experience. This is why it is helpful to go through the app prior to the students using it. It is recommended to have students use headsets for a limited amount of time at once. For example, for third and fourth graders, the limit is 10–15 minutes. This can be adjusted based on the ages of the class. Breaking up students into pairs and having one student on the headset and the other watching what they were doing on an iPad seemed to work well as it also limited the number of students that needed help (Note: The Oculus brand of headsets has a ‘cast’ function built in that allows a headset to do this.). This can easily be done with small groups if headsets are limited. Or, if headsets are unavailable, try finding some content-related 360 videos on YouTube (or create your own in step 2!) so the students can see how the video looks on the screen. Have them view videos on an iPad or smartphone (a desktop/laptop works, but students will have to move their mouse around to see the immersive effects).

**Step 4: Have students create their own VR with 360 video**

Start by introducing the topic that the students should be making a video about. Show examples of the content that was previously created in Step 1 again. One important factor of 360 video is that it is different than a regular camera because the viewer can see everything that is going on around the camera. It would be helpful to show some example videos of ‘good’ camera positioning (see [https://bit.ly/good360Video](https://bit.ly/good360Video) and [https://bit.ly/good360Video2](https://bit.ly/good360Video2)) to show students that the camera captures the whole area around them.

Allow the students the freedom and creativity to choose their own topic, but it does help to approve it to ensure their topic relates to the curriculum. It is also important to remind students of rules with the cameras: do not drop them, treat them with respect, and do not carry them around unless they are attached to a tripod or they are in the box. Instruct the students on how to use the camera and how to record, as many of them are only familiar with smartphone cameras.

Let them try out a few examples before they record their final video. This can help them get used to the cameras and allow them to do some testing prior to the final video. Videos do not need to be lengthy. The creation of the video can be expanded to include storyboards, writing out the lines, and props. There is a lot more that can be done to expand the video-making process if there is enough time to dedicate to this.

After the students are finished recording, help them to upload their videos to YouTube (or upload the videos yourself if this is a hard task). Ensure that the classroom account on YouTube is already logged into the devices. If student iPads are unavailable, the videos can be uploaded on a computer instead. After uploading, create a playlist on YouTube to make it easier to watch the videos all at once. This can be done in the YouTube studio under the Content page and Playlists area. The playlist and videos should be marked as unlisted for privacy reasons. It may be a good idea to send the links to the parents so they can also enjoy what their child created.

**Step 5: Student watch their created VR and reflect**

The final step involves having the students watch the whole classes videos on the VR headset. Prior to this step, ensure the headsets are already logged into the classroom account on YouTube. For Oculus headsets, YouTube is a free app but it has to be downloaded directly onto the headset from the Meta Store. If headsets are unavailable, try iPads or smartphones on the YouTube app. Even without a headset, 360 videos will allow students to move the device around and see the whole viewing area.

One of the most important parts of this step is having the students talk about why they chose their topic. This helps to reinforce the learning and allows them to show what they know about the topic they chose. Tailor the questions to the content that was being covered. Again, 360 and VR can be used for a variety of different content areas, but it worked well in a science module.

The biggest advice for implementing something like this is to try everything before having your students do it. This will help you to feel confident in using this technology, and prepare for the inevitable questions from students regarding navigation or how to do something. There are many benefits of implementing VR and 360 in the classroom and albeit it may feel overwhelming, there are hundreds of resources on YouTube and other sites to help in the process.
REFERENCES


APPENDIX A: ADDITIONAL READINGS IN VR


APPENDIX B: RESOURCES

Brands of 360 cameras: insta360, Ricoh Theta, GoPro
Brands of VR headsets: Meta (Oculus), Samsung, HTC
Insta360 Beginner’s Guide - https://youtu.be/0Nw2XxUBBCE

APPENDIX C: SAMPLE 360 VIDEOS

Letter Learning (Letter B) - https://youtu.be/BmWaoUzCduw
National Geographic - https://youtu.be/sPyAQQkJc1s
Earthquakes - https://youtu.be/q8tz-uzSsJc
Escape to Paris - https://youtu.be/EkshFeLESPUs
Spacewalk - https://youtu.be/hEdzv7D4ChQN
Alone in Space - https://youtu.be/wnrHCMIFNs
Underwater Live - https://youtu.be/eKumVFyGHFAN
Titanic Sinking - https://youtu.be/J-ILijsA9o
Informal learning settings are a commonly used to expose children of a wide range of ages to science and technology topics through fast-paced activities. Sometimes, these activities are designed with a very specific goal and tend to accomplish more than was intended at first. This is the case of a low-cost interactive tool created to be used as an alternate interface to use computer applications while exposing electricity and conductivity topics to visiting school groups. For its construction, we used easy to find materials such as PVC pipes, glue, conductive tape, and wire, while a Makey-Makey board and antistatic wristbands connected it to a computer. Besides the initial aim, repeated use showed how small children enjoyed being exposed to technology and the freedom to control a videogame just by touching each other hands instead of using a keyboard, mouse, or game controller, while some of the older ones started taking leadership roles in the games and getting organized for teamwork. In this chapter, we describe the tool and the activities that were conducted for groups of different ages, along with details on how to replicate the design and create learning activities.

INTRODUCTION

Allowing students of all ages to interact with technology in non-conventional ways creates learning experiences that may spark new abilities and interests. In the case of computers, it is also a strategy to make them more aware of the capabilities of this technology and entice them to this field as a potential career once they get to more advanced levels of education (Ibarra-Esquer et al., 2012). For educators in computer science, it is both rewarding and challenging to create these types of experiences for young learners, who often end up surpassing our expectations, as their imagination and creativity enhance the experience and give insights on how to use technology in learning.

In this specific case, our aim was to create a reusable exhibit for workshops and school visits that could be easily transported, stored, installed, and that was versatile enough to fit a wide range of school levels and students with different skills in using computer technology. Additionally, this exhibit should be independent of the topic or concept being presented, thus helping combine computational thinking development with content disciplines, helping young learners see the real-world application of computational thinking and offering them the opportunity of using it to solve community problems (Ching et al., 2018).

RESEARCH REVIEW

Several studies evidence the importance of informal learning, even estimating it to be around 70–90% of a person’s learning (Latchem, 2014). Museums and science centers are two of the most common resources for engaging in this type of learning (Belin, 2018; Mujtaba et al., 2018; Staus et al., 2021), along with hands-on activities usually performed in science fairs, summer camps, or makerspaces (Anand & Dogan, 2021; Hamidi et al., 2020; Roberts et al., 2018), and the increasing trend to learning in social media (Haythornthwaite, 2022).

As part of their study on this topic, researchers in (Solis et al., 2021) state that interactivity heavily influences learning in science centers. In this regard, museums and science centers are a natural setting for interacting with exhibits,
encountering plenty of examples and guides on their design and implementation (King et al., 2018; Li, 2022). Another study suggests that the use of new human-computer interaction (HCI) technologies can increase children’s attention and improve their experience in using these exhibits (Li et al., 2020).

However, despite all the benefits of learning via interaction that these spaces provide, they require children to visit them, as the exhibits usually lack mobility. This represents an opportunity for alternate ideas built from the experiences reported in studies performed at science centers and enhanced by technology that provides mobility, thus eliminating the requirement for a person to attend a certain place to experience the activity. Low-cost technologies typically used and found in makerspaces can be helpful for designing and creating these types of exhibits and demonstrations.

**IMPLICATIONS**

The idea of creating a new type of interactive activity that presented not only computer-related concepts but also an entertaining and different experience developed as part of the preparations for a two-day workshop where our research group would host students from several local elementary and middle schools to take part in computer science and engineering related activities. Previous experience on the evaluation of technology for teaching computer science (Curlango-Rosas et al., 2012) and collaboration with a local robotics school gave us knowledge of the Makey-Makey board (Figure 1; https://makeymakey.com/). This is an Arduino-based electronics board similar to the command of a game console that a computer detects as if it were a keyboard or a mouse, but instead of pressing buttons, we close circuits using contacts or alligator clips attached to everyday objects, which simulates pressing a button (Román-Graván et al., 2020) and is a popular and affordable tool for informal learning and teaching (Fokides & Papoutsi, 2019; Marín-Marín et al., 2020). These boards can be bought at the Makey-Makey website, where their creators have also arranged a wide set of tutorials and resources to help you get started.

**Figure 1**

*The Makey-Makey board*

The Makey-Makey board attaches to a computer via a USB cable and sends signals corresponding to specific keys or mouse buttons. These signals activate every time there is electrical conduction between the connector corresponding to a key and the ground connector (the metallic stripe labeled as Earth at the bottom of the board). Every time a signal is sent to the computer, the application on screen reacts according to the signal received in the same way it would respond to a keyboard key or mouse button.

After brief experimentation with the board, it seemed appropriate enough to be used as the core of our activity. In brief, it would allow teams of students to interact with a computer application by touching each other’s hands, with the underlying concepts of electricity, microcontrollers, and novel computer interfaces. We decided to use a videogame as the application with which participants would interact, devoting our efforts to the design and construction of the physical device.
First, we designed the activity considering the size of the groups that would attend and the allotted time. The decision was to form teams of four students and assign each of them as the interface for each of the arrow keys; one of them would also act as the ground contact, so every time any of them touched the hand of the ground connector, it would signal her or his assigned key to the computer.

We used a version of the Tetris video game developed in the Scratch programming language as the application (https://scratch.mit.edu/). This game has simple rules and uses the arrow keys to move the blocks left or right, rotate them with the up key, and make them move fast with the down key. We slightly modified the game to progress faster within levels, thus speeding up the increase in difficulty in the game and allowing all the attendees to take part. See Appendix A for additional details on searching for and using games developed in Scratch.

To allow a full team of four to interact with the computer using a single board, we constructed a device like the one sketched in Figure 2. It comprises eight detachable 1-meter PVC pipes and PVC connectors for the corners, arranged as a cube. Four of the pipes form a holding squared base, and the other four are set as posts in each corner of the square.

On top of each of the posts, there is a layer of copper foil tape that serves as the conducting material. The front post has an additional metallic connector for the ground pole. The cube is internally wired and from the bottom of the front posts with the end of each wire connecting to the Makey-Makey board using alligator clips. On each of the connectors, we attached an antistatic wristband, so it would allow the users some freedom of movement and not require them to keep touching the connectors on the posts at every moment, while providing connectivity from them to the post. Figure 3 shows a detailed view of how the components are connected. Each post is glued to its corresponding PVC connector, but the PVC pipes of the base can be detached to fold the device for easy storage and transportation.

**Figure 2**

*Diagram of the interactive device*

In turns, a member of the team was appointed as the ground connector and down arrow. Each of the other members would choose one of the remaining arrows and stand next to their corresponding post, strapping the antistatic wristband to one of their wrists. Team members were instructed to touch the hands of the ground connector once the game started so their corresponding circuit would be closed, and the movement of the block performed in the game (Figure 4). We projected the game on a large screen in front of them so they could observe their actions without an obstructing view.
Figure 3

Connections required for the interactive device

Figure 4

Schematics of the interaction between two participants
The first few teams had some problems coordinating to succeed in the game, but after a few rounds of observation, teamwork started developing and they managed to advance to more difficult levels. Then, the ground connector of one team stood up facing backwards from the screen and took a leadership role instructing the team on how they were going to play and distributing the responsibility on the game actions among all the members of the team. At this point, we realized that our design allowed not only a different way to interact with a computer and present science and technology topics, but it was also a means for strengthening collaboration, communication, and leadership skills.

Most of the further uses of this device we have made have been in exhibitions and demonstrations to high school students who are deciding on a major to pursue. We explained specific technology topics, engaged students in other types of games, and encouraged them to change the connections on the board to better fitting keys according to the needs of the game.

There were a couple of experiences with small groups of children from a community center for infant development who attended the university to take part in STEAM related activities. In this case, the planned activity was to show them how to create quick animations and activities using the Scratch programming language, which worked as intended for the first group. However, the second group ended up being comprised of student with special needs. As such, and with agreement from the center personnel, we changed the activity to using the interactive device and had the children solve simple mazes while holding their hands to a square through the screen to find the path to the exit. In the end, this proved to be a good decision as children were able to complete the activity while having fun and creating a moment of social interaction and learning.

Even though the device was designed and constructed for a very specific activity, it was adaptable enough to be used on several occasions where we have interacted with students of different grades. The way the Makey-Makey board interfaces with the computer makes it easy to select and change activities to suit children and youngsters of different age ranges. This is key to maintaining interest and creating engagement. Any computer game or application can be used; we try to use Scratch for these types of activities as its graphic programming style, based on connecting colored blocks, allows us to show how the games work to students without previous programming experience.

The materials for constructing the device are affordable and readily available. PVC pipes are typically found at any hardware store or home improvement retailer. These pipes usually come in white or dark gray but can be painted to give them a more enticing look. As painting PVC pipes requires some preparation for paint to adhere properly, a good idea is to visit a major retailer and ask if they have colored PVC pipes in stock.

Conductive copper tape and antistatic wristbands can be found at most electronic components stores and require little to no assembly. Antistatic wristbands are usually made for adults; look for those that are adjustable to ensure that, when used by smaller children, they will make proper contact with their skin and the games respond as expected.

The conductive copper tape on the top of the poles serves several purposes: first, it holds the end of the wire that goes inside the pipes and connects to the Makey-Makey board on the other end; second, permits the connection of the antistatic wristband to the circuit (as shown in Figure 3); finally, a single person can control more than one key with the device, or even all of them, touching the copper tape at the top of a pole with one hand, while the other hand touches the ground connector. This way, a team of less than four children can still use the device and complete the activities. A single person controlling more than one key should not wear the antistatic wristbands, as this would close several circuits at once and send more than one key signal to the computer.

In summary, we present the design steps of a low-cost device constructed with easy to find and manipulate materials which is connected to a computer via a device that allows the creation of a wide range of interactive activities. We briefly describe the experiences of use with children and youngsters, so other educators can replicate or enhance them according to their specific learning goals or needs.

REFERENCES


APPENDIX A

Scratch is both a programming language and an online coding community. It is a project of the Scratch Foundation, in collaboration with the Lifelong Kindergarten Group at the MIT Media Lab. Scratch is available for free at https://scratch.mit.edu

As stated on their website, the goal of Scratch is to “promote computational thinking and problem-solving skills; creative teaching and learning; self-expression and collaboration; and equity in computing”. The website contains several resources for parents, educators, and developers, as well as tutorials, starter projects, and activity guides.

Scratch contains a simple visual interface that allows creating digital stories, games, and animations. The Scratch project editor can be used online, on a supported Web browser (Figure 5a), or offline, by installing the Scratch app (Figure 5b) on a computer from https://scratch.mit.edu/download

Figure 5

(a) Scratch project editor running on a Web browser; (b) Scratch app running offline

Projects created in the online editor can be saved to a file on a computer and opened in the Scratch app and vice versa. Both editors have similar functions, but the Scratch app allows you to run your projects even when you do not have access to an Internet connection. You can find a project by browsing through the list of Featured projects in the Scratch Website or typing a description into the search box at the top of the page (Figure 6). The Scratch Team promotes the sharing and reuse of code as a means to spread creative ideas and allow beginners to learn from more advanced users. Any project shared on the Scratch website is available under the Creative Commons Attribution-ShareAlike license. This means that all those projects can be downloaded, modified, and reused by other users. A copied and modified Scratch project is called a “remix”. Remixed projects can be traced to the original, ensuring proper credits are given to every person who has contributed to the remixes.
For the first activity described in this chapter, we downloaded a Tetris game from the address https://scratch.mit.edu/projects/31651654. This project, as well as other similar projects, can be found by typing “Tetris NES” into the search box. After clicking on a project from the search results, the project page is shown on the screen (Figure 7). The game can be played from this page by clicking on the green flag. In addition, the project page shows a list of remixed projects, instructions, credits, statistics, and a button at the top labeled “See inside” that takes you to the project editor (Figure 8). Using the option “Save to your computer” in the File menu of the editor allows you to download the project and open it in the Scratch app. If you have created an account on the Scratch website, the project page also shows a button to remix the project.
Figure 8

*Saving the Tetris game to a file on the computer to open it in the Scratch App*

![Tetris game in Scratch](image)

Figure 9

(a) Page of the Maze project on the Scratch website; (b) One of the mazes in the project with the trail left after moving the square

![Maze project](image)

The second activity involved small children with special educational needs. To maintain them engaged, we selected a maze project (Figure 9a) developed in Scratch that can be opened and played at [https://scratch.mit.edu/projects/95232000](https://scratch.mit.edu/projects/95232000)

Figure 9

(a) Page of the Maze project on the Scratch website; (b) One of the mazes in the project with the trail left after moving the square

This project was developed in an older version of Scratch and works better when downloaded and run from the Scratch app than when played online. We selected it because it is played using the keyboard arrows, making it suitable for our device, and because the square leaves a trail when moved through the maze (Figure 9b), just like if it was being solved on paper; this feature helped children know if they had already taken a wrong path and moved in another direction on the maze.
Supporting Meaningful Learning Experiences with Button-Operated Robots in Early Childhood Settings

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Bringing together recent research on button-operated robots in early childhood settings and developmentally appropriate practices, this chapter details strategies for the integration of robots. Educators are encouraged to design and implement robotics experiences that are intentional, active, constructive, cooperative, and authentic (Howland et al., 2012). To achieve these aims, educators should embed challenges within play-based activities and empower children to set and achieve their own goals. Additionally, educators can support children’s active engagement by selecting a button-operated robot that gives clear feedback and by offering just-in-time support as children address errors in their programs. For constructive learning, educators should prompt children to articulate their programming accomplishments and support their reflection with multimodal materials. When designing the activities, educators should intentionally consider how the activity, materials, and environment may invite or discourage cooperation amongst children. Finally, authentic experiences with button-operated robots in early childhood settings should be play-based and naturally connected to the classroom context.

INTRODUCTION

In this era of one-to-one devices, humanoid robots, and artificial intelligence, technologies play an increasing role throughout our society, impacting even the lives of young children. Amid concerns about the negative impacts that the pervasiveness of technology can have on young children’s development (American Academy of Pediatrics Council on Communications and Media, 2016), the National Association for the Education of Young Children (NAEYC) has encouraged caregivers to responsibly and intentionally use technology to support learning and development (2020). The fast-paced nature of technological innovation, however, regularly surfaces discussion about how to integrate teaching methods and technologies in ways that results in responsible, intentional, and effective practices.

There are many different robots designed for use in preK–12 classrooms, and each has their own way for students to program them. The basic idea of programming a classroom robot is communicating students’ step-by-step directions (i.e., algorithms) to the robot. This programming can be done in different ways, depending on the type of robot. For example, some robots use a scanner to read an algorithm. Other robots require an externally connected device to send them an algorithm. With a button-operated robot, such as the Bee-Bot illustrated in Figure 1, children program the robot tangibly by manually pressing its buttons to communicate their algorithms. Due to their accessibility to even very young students, button-operated robots have sparked much recent research about their place within a preschool learning environment (McCormick & Hall, 2022).

Since button-operated robots are increasingly used in pre-school settings around the world (Terrapin Logo, 2023), this chapter offers an overview of initial research on their integration with young children. Based on these research findings and the authors’ own related studies and experiences, the chapter will detail recommendations for how to intentionally and effectively incorporate button-operated robots to promote learning.
RESEARCH REVIEW

Plowman et al.’s (2010) influential research showed that pre-school children, when playing with computers, could develop content knowledge, technical skills, and dispositions to help sustain their learning. As more recent research extends to other technologies in pre-school settings (Hamilton et al., 2020), similar positive outcomes are evident in the literature on children’s interactions with button-operated robots (Misirli et al., 2019). In their review of literature on robotics in preschool settings, McCormick and Hall (2022) noted that most studies observed sequences and events as learning outcomes. These computational terms closely align with the common curricular goals of following steps and identifying cause/effect relationships. Furthermore, preschool children have demonstrated significant gains in their spatial relations knowledge after playing with button-operated robots (Angeli & Valanides, 2020). Therefore, initial research establishes strong potential for button-operated robots to promote children’s achievement of learning outcomes (i.e., content knowledge).

The idea of young children playing with button-operated robots might initially seem frivolous, but recent research has also documented the development of their technical skills or ability to operate specific technologies through the use of such robots. Notably, however, Newhouse et al. (2017) found that children developed the technical skills to use robots without much adult support but did not tend to achieve other learning outcomes without scaffolding by an adult. While button-operated robots may be valuable additions to preschool learning environments, Newhouse et al.’s (2017) results highlight the importance of appropriate teaching methods. For example, play and guided interaction from adults are critical supports for young children’s positive interactions with digital technologies (Mehta et al., 2020; Plowman et al., 2008). Additional strategies will be detailed in the next section.

IMPLICATIONS

Drawing together recent empirical work on guiding young children’s play with button-operated robots and developmentally appropriate practices (Alqahtani et al., 2022; Hall & McCormick, 2022; NAEYC, 2020), the actionable steps in this section will be organized around Howland et al.’s (2012) five characteristics of meaningful learning: intentional,
active, constructive, cooperative, and authentic. This framework was selected for its alignment with NAICY’s (2020) position statement that, “When truly integrated, uses of technology and media become normal and transparent—the child or the educator is focused on the activity or exploration itself, not the technology” (p. 13). Making learning more meaningful with button-operated robots, therefore, involves strategies that recenter children’s engagement with meaningful activities, exploration, and play.

**Intentional**

The first step toward meaningful integration of button-operated robots is to promote engagement with a problem that children want to solve (Howland et al., 2012). The goals for this kind of intentional engagement are to empower children to solve meaningful problems with tools in their environment, and to give them agency to select and solve the problems (Palmér, 2017).

**Table 1**

*Supporting the Intentional Use of Robots*

<table>
<thead>
<tr>
<th>Instructional Approaches</th>
<th>Highlighted Lesson</th>
<th>Additional Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Select a learning outcome within the content area or developmental domain.</td>
<td>The Bee-Bot Mail activity highlights the intentional use of robots. Note the alignment of learning standards and how the robot supports these goals.</td>
<td>This openly licensed book chapter, <em>Computational Thinking</em>, discusses computational thinking as a set of problem-solving skills and offers a plethora of resources for intentionally using robots and other tools to foster these skills at various grade levels. The lesson planning resources table at the end of the chapter is especially helpful as it lists several resources designed for grades preK-2.</td>
</tr>
<tr>
<td>● Determine if robots can help children achieve the selected learning outcome.</td>
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<tr>
<td>● Design challenges that promote curiosity and exploration.</td>
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<tr>
<td>● Create opportunities for children to have choice and voice in the activity.</td>
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<tr>
<td>● Incorporate materials that foster imaginative and creative play.</td>
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<tr>
<td>● Consider what indicators of learning will be demonstrated through children’s play with the robot.</td>
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</table>

**Embed Challenges within Invitations to Play**

Play is essential for young children’s development, and educators should design experiences that are stimulating, inviting, and filled with choices (NAECY, 2020, p. 22). Rich problems or challenges can be incorporated within these experiences that invite children to investigate and extend their learning (Murcia & Tang, 2019). For example, Hall and McCormick (2022) invited pre-school children to explore how a button-operated robot could help deliver mail throughout the town. Directions and resources for this activity are included in Table 1.

**Encourage Children to Set and Achieve Their Own Goals**

In Figure 2, children were trying to program their mail-carrying robots to travel through a cardboard tunnel. There were several obstacles in this environment, but many children were drawn to this tunnel. The two children in this figure set an initial goal of moving a single robot through the tunnel. After achieving this goal, they set a new goal to have two robots move through the tunnel together (Hall & McCormick, 2022). The environment, materials, ratio of devices to children, and classroom routines can all influence what goals children set. For example, the presence of this cardboard tunnel and the one-to-one ratio of robots to children invited the interactions in Figure 2. Meaningful activities, through intentional design, should encourage children to identify and pursue a goal they want to achieve with their robot.
Figure 2

Children engaging the invitation to play

**Align Early Learning Standards and Child-Generated Goals**

While the activity in Figure 2 could lead to different goals, most child-generated goals involved moving a robot from point A to point B. An early computer science standard is for children to follow an algorithm to complete a task (New York State Education Department, 2020). In this invitation to play, the children had agency to select their tasks and then create the accompanying algorithm. Therefore, the likely child-generated goals supported their achievement of the associated early learning standard. An intentional approach, therefore, will consider how the activity’s design can nurture child-generated goals that align closely with the intended learning outcomes.

**Active**

There is a strong emphasis that young children’s engagement with technology should be active. Children should be able to manipulate the tools and explore how they work, control objects in the surrounding environment, and construct meaning by observing the effects of their actions (Howland et al., 2012). NAEYC and the Fred Roger Center for Early Learning and Children’s Media (FRC) proposed these active interactions should support various forms of play, creativity, and exploration (2012, p. 7). The nature of button-operated robot activities is active, and the following strategies will support young children’s learning from these active experiences.

**Table 2**

*Supporting the Active Use of Robots*

<table>
<thead>
<tr>
<th>Instructional Approaches</th>
<th>Highlighted Lesson</th>
<th>Additional Resources</th>
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</thead>
<tbody>
<tr>
<td>Focus on the children doing the actual work of manipulating the robot.</td>
<td>The <strong>Oh the Places Bee-Bots Go</strong> activity highlights questioning strategies that can support children’s meaning-making when actively using robots. In this activity, robots are integrated in a pre-school blocks center. Facilitators can use the provided question prompts to guide children’s thinking about their robot’s movement through the blocks.</td>
<td>This website gives a concise introduction to debugging programs in language that is friendly for young children: <strong>What Is Debugging?</strong> This blog post includes many debugging strategies that can be adapted for use with young children and button-operated robots: <strong>10 Best Practices for Helping Students Debug their Code</strong></td>
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<tr>
<td>Ask questions that help students make sense of the feedback they receive from their actions.</td>
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<tr>
<td>Guide children’s thinking about the robot’s behavior by providing hints and cues, or by pointing out what peers have done.</td>
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<tr>
<td>Provide just-in-time support as children are debugging errors in their programs.</td>
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Figure 3
Child observing the robot

Select Robot that Provides Clear Intrinsic Feedback

Intrinsic feedback is the information one naturally receives from an action they performed. For example, when a child presses a sequence of buttons on the robot, it behaves in a certain way. Button-operated robots can provide this intrinsic feedback in many ways: making a sound or blinking lights to confirm a button is pressed or that an action has been completed, physically moving in the ways that have been communicated, or leaving a trail of where it has traveled (Alqahtani & Hall, 2022). Children interpret robots’ actions differently, however, and do not always associate it correctly with how they pressed the robot’s buttons (Hall & McCormick, 2022). In Figure 3, the child’s hand to his chin and clenched fist indicate that he is noticing the robot is moving beyond the parameters of the paper. The robot’s movement provides feedback that too many forward buttons may have been pressed. Another child in this study observed that the robot did not move after pressing the “Go” button several times. While feedback (i.e., non-movement) can indicate different actions are required, children may need additional support to respond with a new action.

Scaffold Children’s Debugging Process

Unfortunately, a child’s sequence of steps for the robot may sometimes have an error. When robots do not behave as expected, debugging skills become necessary. Debugging is the process of identifying and correcting errors in a program. To identify the errors, it is necessary to help children link the robots’ actions with the buttons that were pressed (Hall & McCormick, 2022). This need for debugging signals that the child may be reaching beyond what they can perform proficiently on their own. As such, educators should offer just-in-time support or scaffolding for children who are trying to identify and fix errors in their algorithms (Palmér, 2017). Scaffolding may take various forms (e.g., hints, cues, modeling, peer support, adapting activities and resources), but knowing when it is needed and how to individualize it are essential to supporting children’s active use of robots (Murcia & Tang, 2019; NAEYC, 2020).

Constructive

While educators must ensure that children’s experiences with button-operated robots are active, meaningful learning should be a constructive process as well. Aside from manipulating and observing robots, children should express what they have achieved and reflect on their experiences (Howland et al., 2012). Prompting children to articulate their accomplishments can support their social and language development while also sparking their thinking and enhancing their learning (NAEYC, 2020; NAEYC & FRC, 2012). Murcia and Tang (2019), for example, noted that children’s engagement and time spent with robots in their study were positively influenced by, “educators’ questioning strategies and openness to listening to children’s ideas” (p. 11). The following strategies are intended to assist with eliciting children’s thinking and listening to their ideas.
Table 3

Supporting the Constructive Use of Robots

<table>
<thead>
<tr>
<th>Instructional Approaches</th>
<th>Highlighted Lesson</th>
<th>Additional Resources</th>
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<tbody>
<tr>
<td>● Create opportunities for children to talk about and make sense of their experiences with robots.</td>
<td>The Programming Bee-Bots to Draw Geometric Shapes lesson uses children’s drawings and reflection questions to support the constructive use of robots. The article includes directions and files (.stl and .obj) for 3D printing a belt that attaches to Bee-Bots and holds markers. Children can then talk about the drawing their robot made. The questions on page 6 prompt children to reflect upon and discuss what they have achieved.</td>
<td>The Digital Technologies Hub has created multiple robotics lessons for use in early childhood settings. Of note are the varying ways their lessons and resources encourage children’s reflection and meaning making. Class discussions and cloze activities are examples of the varied strategies employed throughout their lessons.</td>
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<tr>
<td>● Ask questions and encourage children to explain what they did, and how the robot behaved.</td>
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<td>● Challenge students to articulate what “worked” when their robot behaved as they expected.</td>
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<tr>
<td>● Point out places where the robot did not behave as expected and ask questions to prompt reflection.</td>
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<tr>
<td>● Encourage children to draw pictures or maps of their robots’ movements to explain their algorithms.</td>
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Figure 4

Child pondering the robot activity

Prompt Children to Articulate Their Accomplishments

Many studies have demonstrated the benefits of asking children to explain what and how they achieved a goal with their robot. Hall and McCormick (2022) noted this was part of the meaning-making process for children in their study, and Alqahtani et al. (2022) had pre-service teachers facilitate conversations with children about what they had achieved with their robot. Given the importance of such discussions and reflection, children should be encouraged to articulate their understandings and accomplishments. See Table 3 for a lesson that purposefully incorporates questions to stimulate children’s conversation about what they achieved with their algorithm and how a change in their algorithm would affect their drawings.

Support Children’s Reflection with Multimodal Materials

Since button-operated robots store the child-generated algorithms in their internal memories, the algorithms can seem invisible to students. This invisibility can hinder reflection and debugging. However, there are several strategies for
making the algorithms visible through varying modalities. The San Francisco Unified School District (2023) has created a series of templates and cards that can visualize children’s plans. In other cases, children have drawn their algorithms on paper or combined drawings with arrow cards (Alqahtani et al., 2022; Palmér, 2017). Finally, Alqahtani and Hall (2022) developed a “belt” attachment that could hold markers and visualize the robot’s path. Using strategies like these to make the algorithms visible can strongly support students’ reflection.

Cooperative

Conversation and collaboration are key to meaningful learning experiences with robots and critical to a healthy early learning environment (NAEYC, 2020). As children learn to cooperatively work together, they learn to care for one another and the community. When robotics activities are designed intentionally, they can foster this cooperative atmosphere and support goals across domains and subject areas (Howland et al., 2012).

Table 4

<table>
<thead>
<tr>
<th>Instructional Approaches</th>
<th>Highlighted Lesson</th>
<th>Additional Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consider making “robot time” a group activity rather than an individual activity.</td>
<td>The Let’s Help Debug! lesson is designed for children to engage as pair of programmers. They learn to take turns with the robot and how to help a partner identify and fix errors in an algorithm. In this cooperative activity, children are formally introduced to a single role (i.e., Driver) while practicing their skills of communication and debugging.</td>
<td>Computer Science in San Francisco has a series of lesson plans for grades K-2 which scaffold toward higher levels of cooperative programming. Eventually, children work in groups of four and have designated roles (i.e., Driver, Navigator, Debugger, and Designer). These roles can be used along with the provided lessons or adapted for use with other robot learning experiences.</td>
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<tr>
<td>Emphasize cooperation and collaboration by assigning roles.</td>
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<td>Have children change roles regularly to vary their experiences working with robots.</td>
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<tr>
<td>Give children prompts or story starters to foster teamwork for sharing about what the robots are going to do.</td>
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<tr>
<td>Ask children to create and share different algorithms that achieve the same objective.</td>
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</table>

Design Activities to Nurture Conversation

Research has uncovered stereotypes of programmers as isolated individuals and has found that most coding apps for young children do not support collaboration (Papadakis, 2020; Radloff & Hall, 2022). Meaningful experiences, however, should encourage conversation and can be designed with that aim. For example, children can be asked to work with a partner to create a story using their robot or choreograph a dance routine with a team of robots (Flannery & Bers, 2013). Although each child had their own robot in the block lesson shared in Table 2, they were challenged to collaboratively construct a world out of blocks for their robot to traverse. The activity, therefore, can be designed to foster conversation when children are working with their own robot or shared one with a friend.
Figure 5

Cooperative filming of robots

Setup Classroom Environment to Cultivate Collaboration

There are many formats (e.g., whole groups, small groups, stations) for organizing learning experiences. Educators can influence learning outcomes by strategically leveraging different learning formats throughout the day. Stations or small groups have worked well to encourage collaboration with button-operated robots (Alqahtani et al., 2022; Hall & McCormick, 2022). Children may engage in parallel play at a station, observe their peers, and attempt copy their sequences; or they may collaborate on a combined problem and share a robot. Alternatively, Figure 5 shows children collaborating to produce a Bee-Bot film during their self-directed play time. Self-directed play has been shown to support learning how to use robots, and making the robots available during these times could spark moments of shared creativity (Newhouse et al., 2017). Additionally, assigning roles on a programming team has been recommended to support collaboration with K-2 learners (Alqahtani & Hall, 2022; Williams, 2017).

Authentic

Play is essential to children’s development, and pretend-play with technologies can be a way to practice skills that transfer to new contexts (NAEYC & FRC, 2012). Therefore, a play-oriented approach can create an authentic context for the integration of button-operated robots (Howland et al., 2012).
Table 5

Supporting the Authentic Use of Robots

<table>
<thead>
<tr>
<th>Instructional Approaches</th>
<th>Highlighted Lesson</th>
<th>Additional Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Utilize existing classroom stations and add robots to the rotation.</td>
<td>Code-IT has published several resources for supporting the integration of button-operated robots. Their Introduction to Programming through Guided Bee-Bot Play module illustrates how play can be an authentic context for integrating robots. After beginning with time for unstructured play, children engage in eight guided-play experiences. Most of these activities pair robots with common classroom materials, and accompanying task cards can help guide children’s play.</td>
<td>The Incorporating Robotics Across the Curriculum article from Edu-topia includes specific suggestions for teachers interested in integrating robotics into active learning experiences across a variety of curricular areas, from math and science to language arts and social studies. Ideas for performance tasks and sample lesson plans are included.</td>
</tr>
<tr>
<td>● Encourage students to program their robots to act out a story they have heard or one they have created.</td>
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<tr>
<td>● Challenge children to develop creative programs for their robots (e.g., making the robot dance along with music, having a robot fashion show where the robot takes a turn down the runway, having a robot race around a track).</td>
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<td></td>
</tr>
<tr>
<td>● Supply various materials for children to create an obstacle course and have their robots navigate it (e.g., applying masking tape to the floor to make robot routes, building mazes with interlocking bricks, or creating cities with wooden blocks or magnetic tiles).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Provide opportunities for self-directed play where children can explore robots in ways that interest them personally.</td>
<td></td>
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</tr>
</tbody>
</table>

**Play!**

The many forms of play, which NAEYC has listed as “self-directed, guided, solitary, parallel, social, cooperative, onlooker, object, fantasy, physical, constructive, and games with rules” (2022, p. 9), can be used to connect characteristics of meaningful learning in a way that is natural and highly beneficial. Planning for play-based integration of robotics may not need to stray far from the established norms and context. For example, existing classroom stations (e.g., blocks/construction, dramatic play, and arts) can be the basis for integrating button-operated robots in a variety of ways that are authentic and seamless (Hall & McCormick, 2022). Whether adapting lessons from this chapter, modifying an existing classroom station, or designing new play-based experiences, the strategies in this chapter can infuse the experience with meaning—making learning with button-operated robots more intentional, active, constructive, cooperative, and authentic.
REFERENCES


## APPENDIX

### Table 6

*Web Addresses for Resources that were Hyperlinked in the Chapter*

<table>
<thead>
<tr>
<th>Resource</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>All lessons and resources that were highlighted in the previous tables are included in this shared folder.</td>
<td><a href="https://bit.ly/highlightedlessons">https://bit.ly/highlightedlessons</a></td>
</tr>
<tr>
<td>Code-IT</td>
<td><a href="http://code-it.co.uk/beebot">http://code-it.co.uk/beebot</a></td>
</tr>
<tr>
<td>Computational Thinking</td>
<td><a href="https://edtechbooks.org/k12handbook/computational_thinking">https://edtechbooks.org/k12handbook/computational_thinking</a></td>
</tr>
<tr>
<td>Computer Science in San Francisco</td>
<td><a href="https://sites.google.com/sfusd.edu/k-2cs/home?authuser=0">https://sites.google.com/sfusd.edu/k-2cs/home?authuser=0</a></td>
</tr>
<tr>
<td>Digital Technologies Hub</td>
<td><a href="https://www.digitaltechnologieshub.edu.au/">https://www.digitaltechnologieshub.edu.au/</a></td>
</tr>
</tbody>
</table>
SOCIAL EMOTIONAL DEVELOPMENT AND INTERACTIVE LEARNING
Anxiety is an ever-present mental health concern affecting children and adolescents, which causes them to feel distress, unease, and intense fear in some cases. Although the feelings of anxiety may vary from learner to learner, it is a concern with real and significant impacts. The impact of a learners’ anxiety can affect their behavioral, social, academic, and overall well-being. School-based interventions can support learners’ emotional well-being. In schools, teachers are uniquely positioned to support learners’ emotional anxiety and well-being. A teacher’s position in the classroom gives them an opportunity to recognize the signs of anxiety in learners, as well as foster an environment of understanding and compassion to meet learner needs. Utilizing technology-based tools can enhance what teachers may be doing to support learners. In this chapter, teachers will learn about free technology apps, online programs, and technology-based activities that can be utilized to manage their learners’ anxiety, enhance the teacher-to-learner relationship, and improve the emotional health and well-being of learners in their classrooms.

INTRODUCTION/CONTEXT

Anxiety is a prevalent mental health concern. Between 2016–2019, approximately 5.8 million children in the United State (ages 3–17) received a diagnosis of anxiety with the majority of those diagnosed in the age 6–17-year-old range. Yet only 59.3% or 6 in 10 children received treatment for their anxiety (Centers for Disease Control & Prevention, 2020). Anxiety can hamper learners’ self-concept, motivation, academic performance, and negatively affect behavior (Fréchette-Simard et al., 2022). Anxiety is a multidimensional construct. Anxiety types consistent in the classroom including: (a) social (including separation anxiety), (b) general, and (c) academic (e.g., inclusive of speaking and test). Prior research has indicated that academic interventions typically do not address achievement; however, teacher-led anxiety reduction interventions do contribute to reduced learner anxiety (Ergene, 2003).

Anxiety is an emotion everyone feels; however, it is also a condition that is both real and significant (Huberty, 2009). Diagnosed or not, learners will experience anxiety in the classroom in one way or another. The general characteristic of anxiety is worry (Vasey et al., 1994). Other characteristics include dread, jumpiness, trouble sleeping, irritability, and anger (Centers for Disease Control and Prevention, n.d.). Therefore, it is important for educators to recognize the impact of anxiety, as it affects a learner’s social, academic, and overall well-being.

There are five common types of learner anxiety. Separation anxiety is when a learner experiences difficulty adjusting to a new environment (Schneider, 2011). Second, social anxiety is when a learner feels anxious in social situations, like around peers (Almeida et al., 2022). Third, performance anxiety is when learners feel stressed or worried over their academic performance in the classroom (e.g., quiz or test [Hill & Sarason, 1996]). Fourth, trauma-based anxiety is when learner’s feel anxiety as a result of a trauma(s) (e.g., abuse, neglect, poverty, gun violence, or a disaster (i.e., natural or man-made) (Schneider et al., 2013). And finally, generalized anxiety is when a learner feels worried all of the time. If left unmanaged, a learner’s anxiety could affect their ability to remember, think, attend class, and behave (i.e., avoidance) (Moran, 2016).

Past methods employed by teachers to reduce learner anxiety have included: (a) sharing picture books; (b) playing music to relax learners; (c) establishing a safe space; and (d) formalized programs. With the advent of technology in the classroom, teachers can employ newer strategies in the classroom to support learners, which includes leveraging tech-
nologies to contribute to learners’ emotional well-being. It is important teachers become aware of the types of anxieties and then find ways to best support their learners. Therefore, the purpose of this chapter is to explore technology tools and practices that teachers can employ as a means to support learners’ well-being.

LITERATURE REVIEW

Technology has been incorporated in school classrooms to reduce anxiety. Studies examining ways to utilize technology in the K–12 classroom to reduce anxiety are rare. However, one study with special education students discovered that playing a virtual reality biofeedback game reduced anxiety ([DEEP], Bossenbroek et al., 2020). Other ways practitioners in K–12 have incorporated technology include video and the Breathe2Relax apps, which promote mindfulness as it has been shown to counter anxiety (Adams et al., 2020). In higher education there are a few studies that explore the use of virtual reality as a means to reduce anxiety. O’Meara et al. (2020) discovered that seeing a green naturalistic forest setting with flowing water through virtual reality devices reduced test-taking anxiety and gave an opportunity for self-described high-anxiety pupils to feel refreshed. Furthermore, in English language learners, technology-enhanced learning experiences helped reduce anxiety related to public speaking (Chen, 2022).

Interventions have been conducted to reduce anxiety in the classroom without the aid of technology. As an example, Larson and colleagues (2010) conducted elevator breathing and guided relaxation to successfully reduce anxiety among 3rd grade students. Brown (2013) conducted an eight-week intervention with elementary students by incorporating positive self-talk, visualization techniques, relaxation strategies, and deep breathing to reduce their anxiety. While these promising practices were conducted without the aid of technology, these techniques can be augmented and enhanced by utilizing online video, virtual or augmented reality, or other applications suggested in this chapter. The following chapter describes tools and ways to utilize technology to reduce anxiety in the classroom.

IMPLICATIONS

Teachers play an important role in helping students with anxiety like recognizing the signs and types of it, while also fostering a safe, supportive, and understanding classroom environment. But teachers do not have to navigate anxiety alone. Teachers should consult with school-based mental health providers, school psychologists/counselors, and their principals to implement the following steps: (a) provide education to learners about the types of anxieties; (b) talk to learners, other teachers, and parents/guardians about anxiety; (c) completing assessments to determine symptoms of anxiety (i.e., cognitive, behavioral, and physiological); (d) train teachers to use relaxation and rehearsal techniques both at home and in the classroom; and (e) help to implement and evaluate interventions (Huberty, 2009). Teachers could utilize technology to support their learners with anxiety. There are different apps teachers can use to support their learners who experience anxiety.

For teachers who have learners with diagnosed anxiety, they can utilize three specific apps to help their learners. The first app is Calm, which offers users the space to learn and practice meditation and relaxation. For example, Calm has been utilized as a three-minute break whole class activity after lunch to help learners refocus through breathing, stretching, and refocusing exercises. Teachers in K–12 have free access to the paid subscription service and access to a library of meditation practices, mindfulness exercises, and soothing music.

A second app is called SAM (Self-help App for the Mind), which is an app that offers tools to monitor moods and feelings as well as provides techniques to manage anxiety. A third app is Happify, which utilizes positive psychology, cognitive behavioral therapy, and mindfulness to break patterns of negative thoughts through activities and games. These apps can be loaded on classroom devices and utilized individually in Elementary classroom centers or during reading time.

For teachers who have learners who have undiagnosed anxiety, or experience anxiety in specific instances, such as prior to exams and or presentations, there are free apps they can use. The first app is Breathing Zone, which allows users to control their breath rate and is great for individuals looking to manage moments of stress and anxiety in the moment. A second app is called Mindshift, which utilizes Cognitive Behavioral Therapy techniques to provide brief relief, reframe anxiety, and begin to overcome fears. The third app is Breathe 2 Relax, which teaches “belly” breathing, supporting the reduction of stress and anxiety. The third app is designed for instances of anxiety, such as the moments before taking a test or an exam, whereas the first two are for learners with ongoing anxiety.
When anxiety turns into behavioral challenges, teachers can use the following apps to navigate issues related to tantrums, discipline, and self-regulation. The first app is Simple Habit, which is an app that offers simple five-minute reflections. Users can personalize their experiences related to focus, fitness, productivity and use to reflect on their actions when discipline may be necessary. There is a kid relaxation (ages 6–11) option. Breathe, Think, Do with Sesame Street, which utilizes Sesame Street Muppets to teach ways to navigate frustrating and upsetting life events. This app is helpful for learners reacclimating to the learning environment after an outburst and or tantrum due to their anxiety. Both apps could be used in morning meetings.

Sometimes teachers have parts of their day when they have unstructured time, free play, or recess. In these instances, learners with anxiety may not be able to navigate these experiences with success; however, teachers can utilize three different apps to structure these times for learners with anxiety. The first app is Insight Timer, an app that offers mindfulness, learning, healing, and stress reduction activities. Other offerings include courses, deep breathing exercises, and guided talks and meditations. The second app is Super Stretch Yoga, which features a superhero leading user through yoga poses and breathing techniques. The focus of this app is on sensory integration, self-awareness, -esteem, and -regulation. And finally, there is Colorfly, which is an online coloring app. Depending on the context, age of learner, and severity of anxiety, any number of these apps could be used in conjunction and modified to the individual learner.

Technology-based Strategies to reduce Test Anxiety

There are several research-based strategies to support those who have test anxiety. One method involves learners writing down their fears and negative thoughts on a digital writing app about taking a test to alleviate anxiety about the test. Past research has indicated an increase in test scores for those with test anxiety when this strategy was employed (Ramirez & Beilock, 2011). Utilizing Google Keep or another digital post-it note application, learners can quickly create a personalized list of their fears and negative thoughts about taking the test.

Another method is belly breathing (diaphragmatic or deep breathing), or the 4, 7, 8 breathing methods (i.e., 4 seconds inhale, 7 seconds exhale, and 8 seconds exhale). Videos found on YouTube support belly breathing as well as the Breathe to Relax app. In practice, teachers arrange a two- or three-minute belly breathing session before oral reading time with the teacher. Images can be projected, and lights dimmed to support a relaxing atmosphere. Belly breathing is a strategy to promote relaxation and reduce anxiety (Larson et al., 2010). It can be utilized at every level of K–12 instruction.

Technology-based ways to reduce Generalized Anxiety

Nature has a calming effect on anxiety. More specifically, naturalness has a calming effect on the classroom environment (Barrett et al., 2015). Going outside is not always an option but there are ways to utilize technology to bring nature into the classroom. Online webcams can be played on presentation monitors within the classroom to bring nature into the classroom. From watching the live underwater reef camera to Yellowstone National Park these venues provide a glimpse of a calming environment while broadening learners’ capacity to focus (see Table 1).

Table 1

<table>
<thead>
<tr>
<th>Topic</th>
<th>Sponsoring Organization</th>
<th>Weblink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underwater Reef Dock Camera in Utila, Western Caribbean</td>
<td>Explore Oceans - Fish, shark, and coral</td>
<td><a href="https://www.youtube.com/live/Kf-x20Yq0_A">https://www.youtube.com/live/Kf-x20Yq0_A</a></td>
</tr>
<tr>
<td>Santa Cruz in Channel Islands National Park Eagle</td>
<td>Explore - Birds, Bats, and Bees</td>
<td><a href="https://www.youtube.com/watch?v=mTsOesC6hE">https://www.youtube.com/watch?v=mTsOesC6hE</a></td>
</tr>
</tbody>
</table>
In the medical field, videos have been used to distract and calm anxiety in patients prior to surgery. The content of the videos was age-appropriate and not necessarily a nature-based video (Milfin et al., 2020). Applying this principle to the classroom has not been empirically evaluated, but it stands to reason that there could be benefits by watching a video clip prior to testing to reduce anxiety.

Anxiety is a common mental health issue that can impact a learner’s personal, social, and academic progress. Schools can be ideal venues for supporting learners with anxiety. In schools, teachers play a critical role in identifying the signs of anxiety and providing learners avenues to reduce anxiety in classrooms. Teachers can modify their instructional practices to support learners’ emotional health and well-being such as meeting learners with understanding and compassion when they feel stressed or worried. Teachers can utilize health and wellness apps in the classroom, which is an emerging area of research and practice. By including age-appropriate apps on classroom devices, teachers can support learners when they are feeling anxious. Further, classroom-based intervention should be deemed an adjunct to professional treatment by counselors and school psychologists and counselors. Therefore, acknowledging professional help for anxiety may lead to reduced anxiety in learners while also strengthening collaboration between teachers and other school personnel.

REFERENCES


Cancer in children is rare. Despite its rarity, it is still the leading cause of death for children and adolescents. There are several uncertainties when a child or teen is diagnosed with cancer. A diagnosis affects a child, their family, and their community. Beyond this, a child’s physical, mental, and academic well-being is also impacted. Teachers play pivotal roles in a young person’s journey with cancer. Most importantly, teachers can create a supportive, connected learning environment, which can be enhanced using technology to meet learner needs. With the ubiquitous nature of mobile technologies, providing support through technological means can provide a sense of routine and normalcy for children with cancer and their families during an uncertain time. Teachers willing to adopt a technical approach demonstrate understanding and compassion for learners with cancer, ensuring educational goals can still be met. In this chapter, apps and other technologies can be employed with children facing cancer and shared with other children in the classroom to build their cancer-specific literacy.

INTRODUCTION

Childhood cancer is devastating. A diagnosis’s physical and mental impact affects families, siblings, and communities and includes disruptions to personal, social, and school life. Childhood and young adult cancer continue to be the leading cause of death for these age groups in the United States (Centers for Disease Control and Prevention, n.d.). It is estimated that 15,000 children under the age of 20 and 21,000 adolescents and young adults aged 20–30 will be diagnosed with cancer (Centers for Disease Control and Prevention, n.d.). In 2021 alone, over 15,000 children and adolescents were diagnosed with cancer (National Cancer Institute [NCI], n.d.). Despite a dramatic drop in death rates (i.e., from birth to 14) of 70%, children and adolescents are still impacted by the varieties of cancer. Therefore, teachers must know how to support their learners with cancer by offering resources to help them succeed in and out of school. However, teachers typically do not receive training on chronic illness and how to meet the needs of their learners (Hinton & Kirk, 2015).

With more technology integration in the classroom, teachers have an opportunity to support and accommodate their learners with cancer. This includes leveraging technology to improve learners’ emotional well-being during and post-treatment. Therefore, this chapter aims to explore technology tools and practices that teachers can employ to support learners’ well-being during and post-treatment with cancer.

RESEARCH REVIEW

Childhood cancer is rare; however, it is the leading cause of death for children in the United States (NCI, n.d.). Among children and adolescents aged 0–19, the most common types of cancer include leukemias, brain, central nervous system tumors, and lymphomas (NCI, n.d.). Since 2018, there have been over 480,000 survivors of cancer (Howlader et al., 2021). Cancer treatments can be attributed to poor school attendance, which may be responsible for academic and social challenges experienced by children reintegrating into school during or after treatment.
Developing a holistic, individualized educational plan inclusive of the physical and psychosocial aspects of the individual leads to better learner outcomes (Lum et al., 2017). Some children’s hospitals have voluntary school programs within the hospital to aid children in keeping up with learning as they are able. Children’s prior school connections are essential even when hospital-based school programs exist.

Adopting technology (e.g., video conferencing) to keep patients in contact with their schools yielded better peer and teacher relationships and improved mood (Ellis et al., 2013). These video chats can be a lifeline for children who face isolation as part of their treatment protocol. Children with cancer can use video technologies to maintain a sense of normalcy (Liu et al., 2015). Not only are communication technologies utilized by children with cancer but educational games, coding robotics, and handheld devices. This chapter discusses technology-based strategies for teachers to implement to support children with cancer.

**IMPLICATIONS**

Children and adolescents with cancer experience physical, mental, and cognitive challenges in the classroom. Some of these challenges include but are not limited to difficulty concentrating because of pain, fatigue, or chemotherapy; emotional trauma from diagnosis; fear of missing school and friends; and social isolation. Teachers can play a palpable role in supporting their learners with cancer. Teachers should be aware of three phases following a cancer diagnosis (a) an initial phase or Phase 1, (b) an ongoing phase or Phase 2, and (c) longer-term or Phase 3. Incorporating these phase conceptualizations will help teachers support their learners with cancer.

Phase 1 usually involves the initial diagnosis, including the complexity, cancer stage, and severity (Kazak et al., 2006). Also included in the initial phase of diagnosis is treatment and its duration, intensity, and type (Kazak et al., 2006). Teachers in Phase 1 must consider that the learner and their families are experiencing potentially traumatic events because of cancer, and schoolwork (i.e., assignments, tests, projects) are not of priority to the learner or family. Therefore, a teacher’s role is to check in with the learner and family to establish a plan to identify and understand a learner’s unique and individual needs while acknowledging their potential physical and emotional limitations.

Another role for the teacher, with caregiver and family permission, is to help alleviate the concerns and fears of the learner’s classmates. Classmates of the learner may ask questions or wonder where and why their peer, friend, and classmate is not in class. Teachers can inform classmates of the reality of living with a cancer diagnosis using technology. For instance, teachers can utilize three free apps (a) Simply Sayin’, which is an app that breaks down confusing terms associated with cancer treatment; (b) Kids’ Guide to Cancer, which is another app that helps young children better understand cancer; and (c) Cancer Crusade, which is a game that increases a users’ awareness of cancer. Utilizing technology makes learning about cancer both engaging and informative.

In Phase 2 of a cancer diagnosis, the learner and their families are sitting with the reality of treatment and the prognosis or outcome of the treatment. In this phase, the initial shock and awe of the diagnosis have somewhat subsided, and learners and their families encounter the demands and challenges of managing a life-threatening illness (Kazak et al., 2006). Learners experiencing cancer experience ongoing events related to cancer, which may include, but are not limited to, (a) repeated hospitalizations, (b) ongoing pain, (c) frequent medical procedures, and (d) potential loss of hair and other body parts (Kazak et al., 2006). Up to 80% of learners and their families experience ongoing stress within the first month (Winston et al., 2002).

Thus, teachers can also provide emotional and social support through technology to stay connected with their learners and peers (i.e., Zoom, FaceTime, Teams). For instance, teachers can normalize a learner with cancer to their peers by Facetimeing the class to the learner who may be at home or in a hospital environment. Using technology in this way, the learner can stay connected at home or in the hospital, and returning to school for them may seem less awkward. Also, part of this phase is the potential return of the learner to school-based activities; therefore, teachers need to, again, be aware of the unique needs of the learner and their families. Teachers can encourage families to check with hospital social workers to see if a school program exists within the hospital so children temporarily separated from school environments can continue their academic studies. One such program in a children’s hospital hosts a school for children to engage in intellectual pursuits. In this setting, teaching interns interact one-on-one with children as they can.

Often, this looks like creating flexible schedules through chemotherapy treatments, hospital visits, and unexpected injuries. Moreover, regarding assignments, teachers can provide flexibility in selecting due dates. Teachers could work with parents and guardians to organize schedules and tasks using CancerCare by CureSearch, an app that collects and syncs medical appointments and side effects with personal calendars. Teachers and learners with cancer, and their peers
may reconnect in the classroom. Thus, there may be a reconnection between learner and their peers that needs to be facilitated by the teacher. To do this, a teacher can also implement cancer-related app games to further educate classmates, such as Cancer Blockade, which provides education about cancer by having users destroy cancer cells. Another app teachers could utilize is Re-Mission 2: Nanobot’s Revenge, which helps young people increase their positive emotions and work toward changing their attitudes toward cancer. In the event a learner with cancer is experiencing ongoing pain and stress, the teacher can track the learner’s pain, like monitoring glucose levels for learners with diabetes, with Pain Squad, which is an app that helps children and adolescents track their pain like a diary.

Phase 3 is the long-term impacts of cancer, which may or may not include a cure, relapse of the disease, or death. Fortunately, more and more children are surviving well into adulthood due to recent medical advances and breakthroughs. Phase 3 incorporates 6 to 12 months post-diagnosis, and depending on the stage of treatment, teachers still need to work with parents and guardians to understand the learner’s unique needs. Some apps teachers could use to educate themselves, their peers in the classroom, and parents and guardians is Cancer.net Mobile, an app that navigates the phases of an illness from diagnosis through treatment and beyond. Another app with a similar function is Pocket Cancer Care Guide, which guides the individual user (i.e., teacher or learner) to build a guide of questions to ask medical professionals through every stage of cancer and its treatment.

Finally, other technology applications teachers could implement include telepresence robots. Teachers could utilize telepresence robots, which can be employed to connect children with the school learning environment physically. Another telepresence robot, VGo, provides a physical presence at school while the child is in the hospital or home, controlling the robot through a mobile device. The robot’s mobility affords the learner access to electives, changing classes, and attending lunch, unlike Zoom or Google Meet, which is stationary access to the classroom. Telepresence robots can ease the child’s reintegration into school (Powell et al., 2021).

Unfortunately, children and adolescents continue to experience and die from cancer. However, teachers can uniquely support their learners with cancer by supporting their social and academic needs. Providing a phase model framework allows teachers to attend to the learner with cancer, the learner’s peers and classmates, and the learner’s families. Teachers are critical in providing a supportive learning experience and ensuring learners have the same educational opportunities. Teachers can do their part to support learner success by utilizing the strategies and apps above.

REFERENCES

Exploring Elementary School Teachers’ Experiences of teaching Social and Emotional Learning with Digital Technology

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This mix-method study explored how elementary school teachers in the United States integrate digital technology into social and emotional learning (SEL) to support students’ emotional well-being and academic success, using the Collaborative for Academic, Social, and Emotional Learning (CASEL) framework to establish fair learning environments that foster both emotional and academic growth among students. This study is conducted in two phases. In the first phase of the study, 350 elementary school teachers completed a survey using a Likert scale and multiple-choice questions to provide insights into their perceptions of using technology to teach SEL. The results indicated that teachers value integrating digital technology into SEL education, as they believe it promotes emotional well-being, academic success, equity, and engagement in learning. However, the study also identified challenges teachers face when integrating digital technology into SEL education, such as ensuring sufficient time for SEL education in schools. The second phase involved conducting in-depth interviews with ten teachers from different states, teaching positions, and years of experience. The findings suggested ongoing training and support are essential for managing teachers’ workloads. Additionally, there is a need for suitable and practical digital SEL resources for younger students and training in balancing digital and in-person SEL interaction to support students’ emotional and academic well-being. Overall, the study provided practical digital tools for teaching SEL and insights into effectively integrating technology into SEL. These findings have implications for guiding teachers on how to improve their instructional practices in SEL education.

INTRODUCTION

The COVID-19 pandemic presented a significant challenge for students, causing increased psychological stress and a shift in overall well-being due to distance learning and isolation (Asanov et al., 2021). Challenges such as distractions, separation from peers, an overload of assignments, and the loss of loved ones can adversely affect students’ academic, psychological, and developmental accomplishments (Duraku et al., 2020; Singh et al., 2020). Therefore, more than ever, it is urgent to teach children about mastering the emotions that help them develop coping skills to keep them mentally strong regardless of what life brings.

Digital technology has become increasingly popular and can help support social and emotional development (Slovak, 2017). As children become more fascinated with digital technologies and multimedia programs, they can be useful tools for directing their attention toward specific tasks in teaching SEL (D’Amico, 2018). Technology is most effective when utilized to evaluate and teach SEL skills while providing extra practice opportunities for students to transfer these skills from the classroom to everyday life (Slovak & Fitzpatrick, 2015; Walker & Vender Weidenbenner, 2019).

This mixed-method research study explores how elementary school teachers in the United States integrate digital technology into SEL instruction to support their students’ emotional well-being and academic success. The findings of this study can assist teachers, administrators, curriculum writers, program developers, and policymakers in determining how to incorporate digital technology into SEL in elementary education. The results can provide teachers with coaching and professional development opportunities on integrating digital technology into SEL instruction to support their students’ emotional and academic development.

RESEARCH REVIEW

This study examined how elementary school teachers in the United States utilize digital technology to teach SEL skills. The study collected data from 350 teachers (see Appendix A) and conducted qualitative interviews with ten teach-
ers (see Appendix B). The findings revealed that teachers use various digital tools, such as GoNoodle, Smartboard, Ka-hoot, Class Dojo, Google Forms, and SEL videos, to incorporate technology into their SEL practices as seen in Table 1. These findings demonstrate the wide range of digital tools available for teachers to integrate technology into their SEL practices.

Table 1

*How Teachers Implement Digital SEL in the Classroom*

<table>
<thead>
<tr>
<th>Digital Tool</th>
<th>%</th>
<th>Number of Choices Made by Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoNoodle</td>
<td>17.12%</td>
<td>120</td>
</tr>
<tr>
<td>Smartboard</td>
<td>15.55%</td>
<td>109</td>
</tr>
<tr>
<td>Kahoot</td>
<td>10.70%</td>
<td>75</td>
</tr>
<tr>
<td>Others</td>
<td>10.41%</td>
<td>73</td>
</tr>
<tr>
<td>Class Dojo</td>
<td>9.99%</td>
<td>70</td>
</tr>
<tr>
<td>Google Forms</td>
<td>7.99%</td>
<td>56</td>
</tr>
<tr>
<td>Flipgrid</td>
<td>4.85%</td>
<td>34</td>
</tr>
<tr>
<td>Tablets</td>
<td>4.14%</td>
<td>29</td>
</tr>
<tr>
<td>Seesaw</td>
<td>3.71%</td>
<td>26</td>
</tr>
<tr>
<td>Padlet</td>
<td>3.28%</td>
<td>23</td>
</tr>
<tr>
<td>Edpuzzle</td>
<td>3.14%</td>
<td>22</td>
</tr>
<tr>
<td>IXL</td>
<td>2.85%</td>
<td>20</td>
</tr>
<tr>
<td>Video Games</td>
<td>2.43%</td>
<td>17</td>
</tr>
<tr>
<td>Freckle</td>
<td>1.43%</td>
<td>10</td>
</tr>
<tr>
<td>MobyMax</td>
<td>1.14%</td>
<td>8</td>
</tr>
<tr>
<td>Socrative</td>
<td>0.57%</td>
<td>4</td>
</tr>
<tr>
<td>Prezi</td>
<td>0.43%</td>
<td>3</td>
</tr>
<tr>
<td>Storypark</td>
<td>0.14%</td>
<td>1</td>
</tr>
<tr>
<td>Virtual Reality</td>
<td>0.14%</td>
<td>1</td>
</tr>
<tr>
<td>Listenwise</td>
<td>0.00%</td>
<td>0</td>
</tr>
<tr>
<td>Clickers</td>
<td>0.00%</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>701</td>
</tr>
</tbody>
</table>

Additionally, the research findings indicate that most teachers integrate SEL instruction into daily lessons (Table 2). However, the study highlights that the time allotted for SEL education is generally limited, typically 5 to 10 minutes per day (Table 3).
The study utilized a Likert scale to gather data from 195 teachers on their attitudes toward incorporating technology in SEL instruction. The scale ranged from 1 to 5, with five indicating “strongly agree” and one indicating “strongly disagree.” The findings indicate that most teachers believe using technology in SEL positively impacts students’ emotional well-being and academic success, as shown in Table 4. The high mean and mode values of the Likert scale suggest that teachers perceive technology as a valuable tool in SEL instruction. However, the study also revealed that teachers reported a lack of professional development in implementing technology for SEL, as evidenced by low mean and mode values (Table 4). This could be an obstacle to successfully implementing digital SEL programs in schools.

The study used a statistical tool called the Spearman correlation to investigate the relationship between teachers’ frequency of using technology in SEL instruction and their beliefs in its effectiveness. The correlation coefficients ($R_s$) in Table 5 show a positive relationship between the variables. The $R_s$ score of +1 means a perfect positive relationship, -1 means a perfect negative relationship, and 0 means no relationship. A $p$-value is also used to determine how significant the relationship is. If the $p$-value is below 0.05, it is considered statistically significant. The results of $R_s$ indicated a positive relationship between using technology to teach SEL and teachers’ belief in effectiveness (Table 4). This suggests that when teachers perceive technology as an effective tool for SEL instruction, they are more likely to use it frequently. The $p$-values of 0.001 in Table 4 demonstrate that this relationship is statistically significant, which means the findings are strong and trustworthy.
Table 4

Ranking of Digital SEL Attitudes of Participants

<table>
<thead>
<tr>
<th>SEL Attitudes Survey Item</th>
<th>Mean</th>
<th>Mode</th>
<th>n (Sample Size)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survey Item 20</strong>: Students learn SEL skills effectively through digital technologies.</td>
<td>3.89</td>
<td>4</td>
<td>195</td>
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<tr>
<td><strong>Survey Item 21</strong>: Teaching SEL through digital technologies positively affects elementary students’ emotional well-being.</td>
<td>3.94</td>
<td>4</td>
<td>195</td>
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<tr>
<td><strong>Survey Item 22</strong>: Teaching SEL through digital technologies positively affects elementary students’ academic performance.</td>
<td>3.92</td>
<td>5</td>
<td>195</td>
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<tr>
<td><strong>Survey Item 23</strong>: I feel comfortable implementing technology in teaching SEL.</td>
<td>4.21</td>
<td>4</td>
<td>195</td>
</tr>
<tr>
<td><strong>Survey Item 24</strong>: I have received professional development from my school in how to integrate digital technology tools in SEL.</td>
<td>3.07</td>
<td>2</td>
<td>195</td>
</tr>
<tr>
<td><strong>Survey Item 25</strong>: I receive support in implementing digital technologies into SEL from my administration.</td>
<td>3.47</td>
<td>4</td>
<td>195</td>
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</tbody>
</table>

Note. Strongly Agree = 5, Agree = 4, Neither Agree nor Disagree = 3, Disagree = 2, Strongly Disagree = 1

Table 5

Spearman’s Correlation Coefficient for Participants’ Digital SEL Attitudes and Practices

<table>
<thead>
<tr>
<th>Variables</th>
<th>( R_s )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of using digital SEL in the classroom and teachers’ perception of elementary students effectively learn SEL skills through digital technologies</td>
<td>0.279</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frequency of using digital SEL in the classroom and teachers’ perception of teaching SEL through digital technologies positively affects elementary students’ emotional well-being</td>
<td>0.281</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frequency of using digital SEL in the classroom and teachers’ perception of teaching SEL through digital technologies positively affects elementary students’ academic performance</td>
<td>0.292</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frequency of using digital SEL in the classroom and feeling comfortable implementing technology in teaching SEL</td>
<td>0.291</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Note. \( n = 195 \), where \( n \) represents the sample size.

**IMPLICATIONS**

This study highlights the importance of incorporating digital technology in teaching SEL. It provides insight into how elementary school teachers perceive and currently use technology to teach SEL. The conclusions drawn from this study suggest implications for professional practice to improve digital technology use in SEL education. Based on the findings, the following suggestions can be made for teachers to enhance the implementation of digital SEL in the classroom.

**Prioritizing SEL Integration in Schools with Maximizing Time.** Based on the study findings, teachers face challenges in incorporating digital technology into SEL lessons. This can also result in limited time allocation for SEL lessons, making it challenging to effectively incorporate digital technology in the classroom (Jones et al., 2017). Schools should prioritize and support the integration of SEL into their curricula by providing resources and training to teachers.
Schools could consider setting aside dedicated time daily for SEL activities or incorporating SEL into other subjects to increase the frequency of SEL implementation. When it comes to prioritizing SEL integration in schools while maximizing time, teachers can consider the following suggestions:

1. Start small: Incorporating SEL into the curriculum can feel overwhelming, especially when time is limited. Begin by initially selecting one or two key SEL competencies to focus on, such as self-awareness or social awareness. Once these are established, more can be added over time.
2. Integrate SEL into existing lessons: Rather than treating SEL as a separate subject, incorporate it into existing lessons. For example, during a science lesson, discuss how emotions impact decision-making.
3. Integrate SEL into morning meetings: One way to integrate SEL into morning meetings is by inviting students to share their emotions using visual aids displaying different facial expressions for each emotion (see Appendix C). By incorporating SEL in this way, teachers can foster a positive classroom culture where students feel valued, supported, and safe.
4. Use digital technology wisely: While technology can enhance SEL lessons, it should be used strategically. Rather than relying on technology for everything, find a balance between digital and non-digital activities.
5. Collaborate with other teachers: Collaborate with other teachers to create a school-wide approach to SEL integration. This can ensure that the efforts are consistent across grade levels and subjects.
6. Seek out training and support: Seek professional development opportunities or resources to enhance your understanding of SEL integration and digital technology. This can help in incorporating effective strategies and approaches in the classroom.
7. Make SEL a priority: Set aside time for SEL activities each day or week. This can help make SEL a priority and ensure it is consistently incorporated into the curriculum.
8. Involve parents and caregivers: Engage parents and caregivers in the SEL process by sharing resources and updates about SEL lessons. This can help extend SEL beyond the classroom and into the home environment.

Balancing Digital and In-Person SEL. The study findings suggested that teachers face unique challenges when it comes to balancing digital and in-person SEL activities in the classroom. Balancing between digital and in-person SEL activities is essential to maximize their benefits and minimize potential drawbacks. Here are some suggestions to help teachers manage this balance effectively:

1. Establish clear guidelines: Set clear guidelines for screen time and use these guidelines to regulate the amount of time students spend on digital SEL activities. The guidelines should also include the frequency and duration of in-person SEL activities.
2. Incorporate various activities: Incorporate various digital and in-person SEL activities to keep students engaged and interested by considering the learning styles and preferences of students.
3. Monitor student progress: Regularly monitor student progress and adjust the balance between digital and in-person activities. This will ensure that students benefit most from both types of activities.
4. Seek support from schools and districts: Schools and districts can provide resources, tools, and policies to help teachers manage screen time in the classroom. Seek professional development opportunities to learn how to balance digital and in-person SEL activities effectively.
5. Involve parents and caregivers: Involve parents and caregivers in balancing digital and in-person SEL activities by sharing information about the activities and guidelines for screen time at home.

Age-Appropriate SEL Programs. The study findings revealed a need for more suitable digital SEL programs for younger students that are developmentally appropriate and engaging. Utilizing appropriate digital SEL programs for young students can help build their emotional intelligence, resilience, and well-being, making them better equipped to navigate the challenges of the modern world (Durlak et al., 2011; Jones & Kahn, 2017). By considering these factors, teachers can select SEL programs that effectively support students’ SEL skills to integrate technology into their instruction. When searching for digital SEL programs for younger students, teachers should consider the following suggestions:

1. Consider the developmental needs of students: Consider the developmental needs of students when selecting digital and in-person SEL activities. Younger students may benefit more from in-person activities, while older students may prefer digital activities.
2. Evidence-based: Look for programs evaluated and shown to have positive outcomes. The program should be backed by research and proven effective in promoting SEL skills.

3. Comprehensive: The program should cover a range of SEL skills, including self-awareness, self-management, social awareness, relationship skills, and responsible decision-making.

4. Interactive: The program should be interactive and engaging, with activities and games that keep younger students interested and motivated.

5. Easy to use: The program should be easy to use, with clear instructions and user-friendly interfaces.

6. Inclusive: The program should be inclusive and culturally responsive, considering students’ diverse backgrounds and experiences.

Equity in Education by Addressing the Unique Needs of Special Education Students through SEL. The study suggests that incorporating technology in teaching SEL in Special Education classrooms can bring potential benefits. However, teachers must consider the unique challenges students with special needs face. Therefore, using digital SEL tools and programs tailored specifically to the needs and challenges of Special Education students is essential for acquiring the necessary social and emotional skills for success in and outside school. Here are some specific suggestions for teachers based on empowering the unique needs of Special Education students through digital SEL:

1. Attend professional development workshops: Attend professional development workshops to learn about digital SEL programs and how to integrate them into Special Education classrooms effectively. This will give teachers the necessary skills and knowledge to help students develop essential social and emotional skills.

2. Use multimedia elements: Incorporate multimedia elements like videos and animations into digital SEL programs to support different learning styles and abilities. This will help engage students and improve their understanding of the material.

3. Monitor student progress: Collect and use data to monitor student progress and adjust digital SEL programs accordingly. This will help ensure that students are making progress and that the programs are effective in helping them develop social and emotional skills.

Create a Curriculum that Integrates Technology and SEL. The study recommends aligning SEL standards with the CASEL framework and setting clear learning goals that focus on both technology and SEL. This approach can help ensure that the SEL curriculum meets state standards and improves students’ social and emotional skills. To achieve this, teachers should receive detailed guides on how to create SEL lessons by incorporating technology, managing screen time, and interacting with students. Here are some practical tips to help teachers create a curriculum that integrates technology and SEL effectively:

1. Align with the CASEL framework: Aligning the SEL standards with the CASEL framework can ensure that the curriculum is evidence-based, comprehensive, and addresses the five core competencies of SEL (see Appendix D).

2. Clear learning objectives: Create clear learning objectives focusing on technology and SEL and aligning with state standards can help keep the curriculum focused and measurable.

3. Prioritize SEL instruction: Prioritize SEL instruction by allocating dedicated time in the daily or weekly schedule for managing SEL time. This can help ensure that SEL instruction is not overlooked or rushed.

4. Integrate digital tools in SEL curriculum: Use digital tools to both create dynamic and interactive learning opportunities that enhance students’ social and emotional competencies and to track and collect data on students’ progress in developing these skills. GoNoodle, Smartboard, Kahoot, Class Dojo, and SEL videos are just a few examples of tools that can be used to promote active participation and engagement in SEL instruction. Additionally, tools like Google Forms and Class Dojo can gather feedback, monitor student behavior, and assess students’ comprehension of SEL concepts. By utilizing these digital tools effectively, teachers can provide a more comprehensive and personalized approach to SEL instruction.

5. Consider digital tool limitations: Recognize potential challenges and limitations of digital tools, such as the need for reliable internet access and technology infrastructure, concerns about privacy and data security, and the potential for over-reliance on technology.

6. Emphasize Digital Citizenship: Integrate Digital Citizenship into SEL lessons by discussing topics such as cyberbullying, digital footprint, privacy, and security. This helps students create positive online identities and
use social media responsibly, fostering essential skills and habits for navigating the digital world and promoting emotional well-being (see Appendix E).

7. Use online resources: Use online resources, such as virtual field trips or videoconferencing, to expose students to diverse perspectives and cultures (see Appendix F).

Providing Ongoing Support and Professional Development. According to the study, teachers require ongoing training and support to effectively integrate digital SEL into their teaching while managing their workload and providing space for SEL education. Schools and districts should provide adequate and ongoing professional development and training opportunities for teachers to improve their skills and confidence in using digital technology in SEL instruction. The success of digital SEL depends on teacher comfort and confidence with technology (Poulou et al., 2018). Training helps build their skills and confidence to integrate technology effectively in the SEL process. Digital SEL delivery requires digital skills, knowledge of technology, and an understanding of how students learn online (ISTE, 2016). Here are some suggestions for teachers to receive ongoing support and professional development in integrating digital SEL into their teaching:

1. Attend professional development workshops: Attend workshops that focus on integrating technology and SEL in the classroom. These workshops can provide teachers with the latest strategies and tools for instruction.
2. Collaborate with colleagues: Collaborate with colleagues to share ideas and strategies for integrating digital technology and SEL in their instruction. This can create a supportive community of educators who can learn from each other.
3. Utilize online resources: Utilize online resources such as webinars, podcasts, and blogs that focus on integrating digital technology and SEL in the classroom. These resources can provide teachers with new ideas and strategies to try in their instruction.

REFERENCES


## Location Demographics of the Survey Participants

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## APPENDIX B

### Demographic Information of the Interview Participants

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<th>School Type</th>
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<td>16 +</td>
<td>Suburban</td>
</tr>
<tr>
<td>Participant B</td>
<td>UT</td>
<td>Sped</td>
<td>1 to 5</td>
<td>Urban</td>
</tr>
<tr>
<td>Participant C</td>
<td>NJ</td>
<td>Music</td>
<td>1 to 5</td>
<td>Suburban</td>
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<td>Participant D</td>
<td>AL</td>
<td>ELA</td>
<td>1 to 5</td>
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<td>CA</td>
<td>Gen Ed</td>
<td>11 to 15</td>
<td>Urban</td>
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<td>ND</td>
<td>Gen Ed</td>
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<td>NM</td>
<td>Gen Ed</td>
<td>6 to 10</td>
<td>Suburban</td>
</tr>
</tbody>
</table>
APPENDIX C

An Example of Visual Aids for Supporting SEL

Note. Shared with permission from Participant C.

APPENDIX D

The CASEL Framework and Interactive CASEL Wheel Explaining Five SEL Competences

https://casel.org/fundamentals-of-sel/what-is-the-casel-framework/

APPENDIX E

SEL and Digital Citizenship Resources Recommended by CASEL


APPENDIX F

Virtual Field Trip Apps and Websites (30 Digital Tools)

“How Do We Know Technology Can Help Us Teach This?”: Using the Technological Instructional Overhead Inventory to Evaluate the Cognitive Load of Technology Adoption.

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The wide range of technologies currently available to teachers can make selection and use of them overwhelming. While some technologies are rapidly taken up within K–12 classrooms, others remain dusty artifacts in the back of the classroom that never see the light of day. Understanding what impacts technology adoption can help educators make sound decisions about when and how to engage with technology. By assessing the associated cognitive load of technology adoption, teachers, administrators, and professional development (PD) providers can better assess the suitability of specific technologies for specific teachers and classrooms. This chapter explores notions of technological instructional overhead (TIO) and how it influences and impact teachers’ decisions to use or avoid specific technologies within their classrooms. Through a series of case examples, this chapter explores the differences in instructional overhead offered by various technologies and explores the supports needed for teachers to successfully use technologies within their classrooms. Written for practitioners, this chapter will lay out reflective questions that teachers can ask themselves before they engage new technologies in their classrooms. By exploring these questions, practitioners can assess the potential value of a specific technology verses the technological instructional overhead.

INTRODUCTION

A frequent conversation among educational technologists is pondering exactly why classroom teachers often do not opt to engage technology within their classrooms. Why, oh, why can’t teachers see the value of the technology they are offered? Are teachers just resistant to change? Unlikely. Are they under-supported through training and incentives to engage with novel technologies? Usually. Are there other factors that teachers consider when deciding whether to adopt a novel technology within their classroom? Definitely.

There are several factors that might impact teachers’ adoption of novel technologies. Available time within the class curriculum, interest, and self-efficacy might all impact how and why a teacher may adopt technology within their classroom. Furthermore, teachers are often provided insufficient professional development and classroom resources to feel strongly efficacious in engaging new technology. Who can blame teachers for shying away from learning technologies that often require learning on their own time, procurement with their own monies, and potentially take time away from core learning content? Furthermore, teachers often report technology’s everchanging face leaves them feeling weary, noting that classroom technology advocates often suffer from “shiny object syndrome,” fluttering from new technology to new technology without regard for the pragmatic considerations of classroom work (Orlando, 2014). Despite these barriers, most teachers are open to engaging students in learning about and with technology. Teachers recognize the inherent value of rich technology-driven learning experiences for their students (Ottenbreit-Leftwich et al., 2010). Technological
instructional overhead (TIO) is a way of framing and examining the potential benefits of specific technologies against barriers to use.

TIO considers multiple forms of overhead that span the logistical (e.g., time and resources), the motivational (e.g., self-efficacy and value for the task), and the cognitive (e.g., the amount of mental effort demanded). While much as been written about the instructional decision making and motivations of teachers, there has been surprisingly little research examining the way that teachers cognitively process information. Universal features of human cognitive architecture affect the reasoning and actions of teachers in the same ways that they do any other learner or professional. Their capacity to process new information is limited to about 3–5 items within their working memory, and it is effortful to do so. The process of developing expertise requires both time and effort to integrate new information into efficient knowledge structures that will permit them to act fluidly and effectively in the classroom (Feldon, 2007). This chapter provides the framework and tools for helping various school stakeholders such as teachers, administrators and PD providers make informed decisions about what technology works best in specific spaces and how likely uptake may be.

**RESEARCH REVIEW**

Technological Instructional Overhead (TIO) is the idea that technology requires teachers to make decisions about what technology they engage in their classrooms based on an evaluation of what they need to put in compared to what their students potentially get out of the technology. It operates on the basis of the cognitive tradeoffs that teachers must make every day as they engage with students and school structures. In an environment overflowing with information that may inform instructional decision making, interpretation of learning needs, and determination of proffered social supports, as well as managing the requirements of curricula, classroom management, and school policies, it is a common occurrence for teachers—especially novices—to feel cognitively overwhelmed by the job (Moos & Pitton, 2014). Information overload can hinder judgment, force teachers to react instinctively rather than deliberately, and even manifest biases that they may not intend (Feldon, 2007).

These events do not reflect shortcomings on the part of the teacher; they are a natural consequence of human cognitive architecture, in which the allocation of limited working memory resources shapes both learning and performance (van Merrienboer & Sweller, 2005). When teachers have well-developed and familiar routines, the management of classroom activities occupies less of their working memory, permitting the allocation of scarce attentional resources to the nuances of students’ learning needs (Thompson et al., 2013). Thus, disruption of those routines to accommodate the integration of new technologies comes at a cognitive cost, which can undermine self-efficacy (Feldon et al., 2019) and contribute to professional burnout (Friedman, 1996; Newberry, 2013). However, teachers may choose to change those routines if they feel that the return of investment on that mental effort is likely to benefit their professional practice or the learning of their students.

Practical barriers, such as lack of funding (Wachira & Keengwe, 2011) and time (Sugar et al., 2004) have been documented. However, research has also documented various teacher characteristics that go into their technological decision making. For example, teacher concerns about technology are a determining factor in their adoption of classroom technology (Hope, 1997), including self-efficacy, attitudes, and resistance to change (Ottenbreit-Leftwich et al., 2018).

Additionally, teachers determine technology integration as a pedagogical decision. Adopting the concept of Pedagogical Content Knowledge from Shulman (1986), Koehler & Mishra (2005) argued that technology-related decisions are made by the teacher’s content knowledge, pedagogical knowledge, and technology knowledge. Further, teachers ultimately will evaluate the instructional efficacy of the technology during in-the-moment decision making by looking at the interaction between the teacher, the students, and the technology used (Anderson et al., 2017).

TIO is the term we use to describe the process of evaluation that teachers engage to evaluate the potential value of a technology in their classroom. The first thing teachers must evaluate is how much cognitive effort or work must go into their own mastery of the technology sufficient to teach it. Assuming that the cognitive cost of learning the technology seems manageable, the teacher must then evaluate what they must do to teach the technology to their students given the constraints of the classroom in which they work. Finally, teachers must evaluate whether a technology offers their learners something new or better intellectually that would make the instructional load of learning and teaching the technology worthwhile. For example, smartboards were readily adopted by many teachers because teachers found them easy to use and highly worthwhile at managing information and tasks within the classroom (Martin et al., 2014). The relative TIO for the smart board was seen as low because teachers could adopt the technology easily with a high payoff.
IMPLICATIONS

Every day teachers make instructional decisions to best support the learning of their students. When it comes to educational technology, teachers are often driven by time and cost, constraints that permeate every decision they make as professionals. Over the course of a dozen educational technology studies, our team has developed a decision inventory framework for teachers to make pedagogical decisions called the Technological Instructional Overhead Inventory. The TIO inventory is a tool that can help teachers decide if and when a piece of technology might be right to use in their classroom. By answering the driving questions for the inventory, teachers are best able to reflect on their instructional needs and compare that to the TIO of potential classroom use of a technology. While the TIO inventory is by no means an absolute, it does offer teachers a space to reflect on the potential benefits of teaching with a specific technology while also considering the potential instructional and cognitive load engagement with that same technology. In this chapter we share the inventory and two examples of how teachers might evaluate the TIO of two separate technologies within their classrooms.

The Technological Instructional Overhead Inventory asks teachers to reflect on three core areas related to a specific technology: time to learn (TTL), time to teach (TTT), and potential benefits (PB). The first two of these make up the TIO of a piece of technology. The fourth, potential benefits, is what allows teachers to assess if engaging with a piece of technology is worthwhile for them and their students. This assessment will be different for every teacher and potentially for every class of students. The TIO intentionally only takes a few minutes to fill out, so teachers can use it as part of their technology planning process repeatedly. We encourage teachers only to engage technology when the technological instructional overhead is lower than the potential benefits. Low TIO indicates that there is reasonable potential for a technology to be value added to instruction. Figure 1 shows the inventory set of questions.

Figure 1

TIO inventory

Technological Instructional Overhead Inventory

Answer the following questions on a scale from 1-10.
1= NOT AT ALL  10= ABSOLUTELY

1. Is this a technology I am familiar with?
2. Is this technology similar to something I am currently using in my classroom (example: I use an overhead machine in my classroom which is similar to a projector)
3. I think this technology will be quick to learn for me.
4. In general technology is easy for me to learn.
5. Does this technology do something different than other technologies I use?
6. Does this technology do something better than other technologies I use?
7. I think students will learn something new or better by engaging with this technology.
8. Does this technology help me teach something better than the way I teach it now?
9. I think this technology will be quick to learn for my students.
10. I think this technology will be easy to use for my students.
11. I think students will enjoy using this technology.
12. Students will use this technology for multiple ways.

The first thing that the TIO Inventory suggests teachers examine is how much time and effort it will take them to learn a technology sufficiently to teach it. This is captured in questions 1–4. For many educators, there is a desire to have a rich and nuanced understanding of content and tools before they are brought forth to students. Different educators will have greater or lesser prior experiences with different technologies. Many of us will need to grapple with the reality that our students are technology natives while we are not. For every educator, the comfort zone will look and feel different. Understanding their own technological comfort zone and the associated time to learn will allow each educator to assess the first component of instructional overhead. This is the purpose of reflecting on the time to learn a specific technology for each educator.
The second portion of the TIO inventory summarizes what teachers believe they can gain by using a technology within their classroom. For technology to be worthwhile in a classroom setting it must teach something new or something better. Engaging technology within a classroom simply for the sake of engaging with technology is unlikely to develop sustained use. Instead, when teachers are able to engage with technology in service to their broader teaching goals, they are more likely to continue to use it.

The final portion of the TIO inventory looks at what is required to teach students to use the technology. When we teach with technology, it requires an additional level of instruction. Teachers must first teach students to use the technology and then teach the content associated with the technology. Thus, it is important for teachers to assess what they think it will take for them to teach a specific technology to students. Part three of the inventory, questions 9–12, address this construct.

Let’s look at two examples of technologies that teachers might consider for their classrooms—three printers and the University of Colorado’s Natural Selection simulation (https://phet.colorado.edu/en/simulations/natural-selection). 3D printers are often something that teachers do not have prior experience with, require a lot of upkeep and training, and do not always work correctly for students. UC’s simulations, on the other hand, are fairly straightforward and are scaffolded with instructional videos. Figure 2 is one teacher’s example of a TIO for 3D printers. In this image we see that the teacher identifies the 3D printer as a technology with high potential but also high instructional overhead. While the 3D printer does offer learning in a new way, based on the teacher’s responses it also appears that the instructional overhead is high for learning and teaching the technology within their classrooms.

If we look at another example in Figure 3, we see that the teacher feels more comfort with engaging the simulation within their classroom. The simulation appears to offer the teacher a higher learning outcome for students with less cognitive demand and learning on their part.

The TIO inventory is by no means intended to be a standalone decision calculus. The intent behind it is to help teachers quantify some of their perceptions and thoughts about engaging with a specific technology at that time. It is also important for educators to consider the broader context of their classroom, school, and instructional goals. Even if an educator had identified a dozen technologies with very low instructional overhead, it might be imprudent to work on adopting them all within the school year. Alternatively, a teacher might also feel passionately about working with a specific technology that has very high instructional overhead. For example, bio making, a set of technologies that allows students to engage in biological engineering with microbes and other living things to explore biological systems, would typically be considered technology with very high instructional overhead. Typically, teachers need to learn the tools and the higher-level biology behind the projects before even beginning to work with students. Because these technologies are so beyond the typical day to day technology that even relates to classroom instruction, they require a substantial amount of professional development for teacher adoption. However, it is also exactly the novelty and unique nature of the technology that makes them very desirable for some teachers. Thus, a quantification of the technological instructional overhead should not be the sole decider for whether teachers adopt a technology. Instead, an understanding around the TIO associated with a technology can help inform teachers and manage expectations for what the process of technology adoption can and will be like.

Understanding the explicit and implicit draws on time and energy needed to enact new technology within classrooms is essential for supporting teachers. By reflecting on technological instructional overhead, school stakeholders can work collaboratively to identify the most meaningful and viable technologies for engaging in classrooms. In order for technology to be worthwhile for instruction it must engage something new or successfully scaffold learning in more efficient or better ways. Technological instructional overhead allows teachers and administrators to evaluate the potential cognitive load needed to enact a specific technology and weigh that load against other considerations and variables within a specific educational setting and context.
Figure 2

High TIO inventory

Technological Instructional Overhead Inventory

Technology Being Considered: 3D Printers
Grade Level Taught: 8th grade

Answer the following questions on a scale from 1-10.
1= NOT AT ALL 10= ABSolutely

PART 1

1. Is this a technology I am familiar with? 1
2. Is this technology similar to something I am currently using in my classroom (example: I use an overhead machine in my classroom which is similar to a projector) 1
3. I think this technology will be quick to learn for me. 3
4. In general technology is easy for me to learn. 5

= 10

Part 2

5. Does this technology do something different than other technologies I use? 10
6. Does this technology do something better than other technologies I use? 5
7. I think students will learn something new or better by engaging with this technology. 6
8. Does this technology help me teach something better than the way I teach it now? 3

= 24

Part 3

9. I think this technology will be quick to learn for my students. 1
10. I think this technology will be easy to use for me. 3
11. I think students will enjoy using this technology. 3
12. Students will use this technology for multiple ways. 10

= 17

PART 1+ PART 3= 27

PART 2= 24

For this class 3d printers would be deemed: High Technological Instructional Overhead
Figure 3

Example of low TIO inventory

Technology Being Considered: *PHET Simulation-Natural Selection*
Grade Level Taught: *8th grade*

Answer the following questions on a scale from 1-10.
1= NOT AT ALL  10= ABSOLUTELY

**PART 1**

1. Is this a technology I am familiar with? 1
2. Is this technology similar to something I am currently using in my classroom (example: I use an overhead machine in my classroom which is similar to a projector)? 1
3. I think this technology will be quick to learn for me. 7
4. In general technology is easy for me to learn. 5

= 14

**Part 2**

5. Does this technology do something different than other technologies I use? 8
6. Does this technology do something better than other technologies I use? 8
7. I think students will learn something new or better by engaging with this technology. 8
8. Does this technology help me teach something better than the way I teach it now? 8

= 32

**Part 3**

9. I think this technology will be quick to learn for my students. 8
10. I think this technology will be easy to use for my students. 3
11. I think students will enjoy using this technology. 8
12. Students will use this technology for multiple ways. 10

= 29

**PART 1 + PART 3 = 43**

**PART 2 = 32**

For this class the PHET Natural Selection Simulation would be deemed: Low Technological Instructional Overhead
REFERENCES


Developing a Self-Directed Learning Program for Technology Learning

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The constant change and evolution of technology are among the few recognized constants that make it difficult for traditional professional development programs to meet the needs of learners, especially classroom teachers. Self-directed learning presents an opportunity for educators to identify technology to meet their needs, allowing them to use their learning time effectively and efficiently. Implementing a self-directed learning program to support educators can build a learning community and address the deficiencies of traditional technology professional development methods. Because self-directed learning differs for every learner, implementing a support program helps learners develop their skills, share what they have learned, and promote a culture of continuous learning. This chapter outlines the fundamental areas of infrastructure, learning process, and sharing and collaboration needed in a self-directed learning program to support learners to be successful in their learning endeavors.

Keywords: self-directed learning

INTRODUCTION

Technology development has grown exponentially as advancements outpace educators’ and trainers’ ability to develop curricula to address the rate of change, leading to increased anxiety among learners (Henderson & Corry, 2021). Traditional professional development for educational technology training consists of a high-level overview of the technology and suggestions on how to implement it for specific content areas. However, in order for professional development to be effective, the focus should center on content, active learning, collective participation, and the role of technology in the context of learning (Yurtseven et al., 2020). Current educational technology professional development programs are not bounded by researched best practices, and the lack of evidence in areas of sustainability, cost-effectiveness, and identifiable impacts limits the overall view of importance in the current educational climate (Hennessy et al., 2022). The reality of organizations being able to provide effective and efficient professional development that appeals to a wide variety of content areas and provides the support that educators need is unachievable with current models and offerings. Encouraging educators to engage in self-directed learning (SDL) to become familiar with and proficient in utilizing new and emerging technologies will benefit their instruction and their learners in building skills needed for the modern world. SDL is an approach that many educators engage in informally, but developing a formal SDL program will allow educators to adapt and engage with new and emerging technologies.

RESEARCH REVIEW

A growing number of industries demonstrate the need for implementing SDL practices as formal professional development programs cannot meet the needs of learners to obtain and maintain the knowledge needed for changing standards, procedures, and technologies (Lemmety & Collin, 2020; Milligan et al., 2015; Quinney et al., 2020; Raemdonck et al., 2014). Education is no different, with changing curriculum standards and the growing availability of technology and resources (Weller, 2011). While there is no singular definition of SDL, common elements for successful implementation include providing learners with an internal locus of control to identify their learning needs and goals, find relevant resources, develop learning activities and strategies, and determine how they will evaluate their learning (Boyer et al., 2014; Knowles, 1975; Loeng, 2020). While educators live and work in a world of learning, they are not necessarily prepared to engage in all elements of SDL (Steinke, 2012). Developing an SDL program can address knowledge gaps to
promote the successful implementation of SDL (Raemdonck et al., 2014). The development and implementation of SDL programs will allow educators to design and engage in active learning focused on new and emerging technologies relevant to their content. Furthermore, developing an SDL program that builds a community of learners will allow educators to collaborate with others both inside and outside of their content areas (Moller et al., 2005). This collective participation can lead to the beginning of a culture where educators drive technology professional development instead of administration.

**IMPLICATIONS**

It is important to remember that SDL is different for every educator, and they will progress at different paces. Technology learning, in general, is even more difficult as there is a need for technical knowledge, the possibility of limited resources, and many unknown elements that could alter the SDL process. Understanding these barriers means developing an SDL program must be flexible and adaptive to support all educators. Initial groundwork to support the common elements of SDL falls into three areas: infrastructure, learning process, and community development. Additional elements in each area provide further guidance and focus.

**Infrastructure**

**Aggregation of Resources**

Resources available for technology learning grow at almost the same pace as technology changes. The aggregation of current resources is a starting point to create an area where educators can begin their SDL journey and support their learning along the way. The resources should include but are not limited to, existing resources on current technology platforms, existing professional development programs or platforms, and points of contact for current tools and technologies. A common approach is creating a website or shared network drive that educators can easily access. Sometimes finding the appropriate resources can lead educators to give up before they begin their learning journey. To implement SDL practice, educators can work with Information Technology (IT) teams to request a shared drive or create an internal website through designated providers. If these options are not possible, leveraging cloud storage drives like Google Drive or OneDrive allows educators to create easily sharable links accessible to anyone. Additionally, using cloud storage in conjunction with a free websites platform like Google Sites, Weebly, or Wix allows for a customizable solution to organize and categorize resources in a user-friendly manner.

**Pathways to Share and Update**

The vast amount of resources to support technology learning is constantly changing and would be impossible to maintain for all potential technology learning. The ability for educators to share new resources and artifacts of learning is essential in the SDL process and to support the growing learning community. Providing clear pathways for educators to add to current resources will not only further support SDL but also allow for content-specific resources and the identification of preferred resources for future support. Creating these pathways will vary between campus and districts, but developing a standardized process like submission forms, shared email inbox, or designated point of contact will create a clear pathway for the continued aggregation of resources. Free resources are available for educators to create forms from companies like Microsoft and Google, as well as the ability to create custom email addresses for educators to share resources. A designated individual or team will need to check for submissions regularly, and a review process developed to ensure accurate and useful information is shared with the broader learning community.

**Learning Process**

A sample learning plan (Figure 1) provides a basis for educators to implement and follow the outlined learning process. Depending on learning needs and support, additional development of this plan can be undertaken and provide a framework for learners to engage in SDL.
Identifying Needs

The constantly changing nature of educational technology presents a challenge to most educators in narrowing their focus on the best tool to implement. Conducting needs assessments allows educators to identify the pros and cons of their technology interests and identify ways the technology could benefit or harm their teaching practices. Developing a common needs assessment tool applicable across multiple content areas can help educators develop a rationale for choosing their learning pathway. To get started, educators can collaborate to determine where the greatest needs are, how the technology will benefit their learning and instruction, and if the technology is feasible to learn and implement. Using this process can inform the development of a needs assessment for future analysis.

Developing Goals

With technology, it is easy for educators to jump in without a clear goal or outcome. In combination with their needs assessment, educators need to develop clear and measurable goals in order to evaluate their learning throughout the SDL process. This may be a struggle for some educators due to their experience with current curriculum goals, which are clearly outlined and the result of an exhaustive development and review process. Developing resources to assist educators in developing their own measurable goals and outlines on how to achieve those goals can lower the difficulty faced as they develop their learning plan. The utilization of sentence stems, sample goals, and prior examples can lower the barrier faced by new educators in the SDL process. Initial steps in this process include clearly defining what the educator hopes to achieve with the technology and what measurable objectives they will achieve along the way toward reaching their goal. Common taxonomy resources like Bloom’s and Facets of Understanding will guide the development of goals and objectives.
Designing a Flexible Learning Plan

After creating learning goals, the focus shifts to designing a learning plan with activities, strategies, and resources. Identifying potential activities that support learning goals is a great way for educators to develop a pathway to reach their learning goals. It is important to remember that it is very unlikely that educators will know all activities they will need to complete to achieve their goal, so maintaining flexibility in the learning plan is essential for the plan to be adaptive to new discoveries and setbacks. The learning plan is also where educators identify strategies they plan on using in their SDL journey. Again, the learning strategies are flexible as new needs develop and resources are discovered. Finally, the learning plan should contain an initial list of resources to allow them to start on their learning journey; the aggregation of resources will assist them in this process. As educators become more familiar with the technology they are learning, new resources are identified and can be added to the previously aggregated resources. Creating a functional and flexible learning plan will assist educators in getting started in SDL and prevent stagnation during the process, as they have a clear outline of activities to engage in to reach their learning goals. Plans should include a list of activities to achieve their learning goals, an estimated timeline to complete these activities, strategies they will use with these activities, and a list of resources they will use to accomplish their activities. To get started, once educators have identified their desired technology to learn, they should begin to locate resources and use case examples to inform the activities they wish to undertake. As educators engage in these activities, they will be able to identify resources and strategies that best suit their learning and can inform future SDL practice.

Evaluating Learning

Learning evaluation is easy for educators to internalize, but clearly identifying when learning goals are met will support the learning journey and the development of future goals. The easiest question for educators to ask themselves is, “How will I know when I have learned...” In regard to technology, educators may choose to create a learning artifact or implement a process that enhances their capabilities. Identifying clear metrics aligned with their learning goals will also allow for the further development of incremental metrics, allowing for continued evaluation along their learning journey. To start, educators can use their overall learning goal to inform evaluation by reflecting on what they will create or be able to do when they achieve their learning goal. As they identify learning activities, this process repeats with the determination of what activity completion looks like. Again, it is important for educators to state these metrics and record results during the learning process to evaluate their learning properly.

Sharing Learning

Sharing is an easily overlooked step in the SDL journey and allows educators to share with their peers and administration. Educators often only want to share the final outcome or product of their learning, but it is important to share throughout the learning process. The vast nature of technology in education presents unforeseen hurdles, and emerging technology presents new possibilities. Sharing presents additional learning opportunities and is beneficial in helping educators maintain accountability and motivation, which is essential in SDL. As educators engage in the SDL process, scheduling time to share with their peers or learning groups will support their learning journey and present opportunities for feedback. Developing a clear evaluation plan allows educators to identify opportunities to share throughout the learning journey and provide updates on their progress.

Community Development

Collaboration and Presentation

Creation, development, and sustainment of learning communities can be difficult in education environments due to the unaligned schedules, variety of content areas, and differing learning needs. However, providing opportunities to share will allow for networking within and across disciplines. Providing educators with the opportunity to demo their learning
through either synchronous or asynchronous means provides occasions for inspiration and motivation among the learning community as educators are exposed to new ideas from a wide variety of areas. This is especially true with technology learning, as learners are exposed to new technology and resources. Creating scheduled events, recorded presentations, or a centralized hub for educators to share their progress allows for further aggregation of resources and continued development of a learning community. This community growth will allow learners to network and access additional resources as their SDL adapts and changes to their needs. While opportunities will vary between campuses, educators can leverage team planning time and campus-wide meetings to provide updates on their progress and showcase what they have accomplished.

**Celebration of Failures and Setbacks**

Since educators will all be at different stages during the SDL process, it is important to encourage and even celebrate failures and setbacks, knowing that not everyone will be successful in their learning endeavors. Removing the stigma of not achieving learning goals assists discouraged educators in identifying takeaways as they begin their next SDL journey. Emerging and existing technologies are constantly evolving, so the possibility of limited resources or an overwhelming need for technical knowledge presents barriers in the SDL process. Recognizing the difficulty of learning new technologies and creating a culture of continuous improvement creates a strong foundation for learners to maintain motivation even when setbacks occur. Using the designated learning community times allows educators to share why they are unable to continue their learning and what they have learned to inform their next SDL opportunity.

Technology is ever-changing and always moving at a pace too quickly for traditional professional development methods to fully support educators in their implementation. Developing and sustaining an SDL program will allow educators to identify useful technology and develop a learning process to meet their needs. This approach will allow for greater implementation and encourage innovation among educators as they build a learning community that can adapt to the modern world.

**REFERENCES**


APPENDIX A

Self-Directed Learning Resources

Readings

- Self-directed professional development
- Tech Trends to Watch (for Self-Directed Learners)
- Self-directed learning is the key to new skills and knowledge
- 20 Steps Towards More Self-Directed Learning
- Measuring Self-Directed Learning: A Diagnostic Tool for Adult Learners

Videos

- Self-Directed Professional Development
- Learning through self-teaching and experimentation
- Teacher Labs: Making Professional Development Collaborative

Websites

- Self-Directed Learning | Educational Planning
- 10 Free Learning Tools Best for Self Learners

Presentations

- Self-Directed Learning in the Workplace
## Technology Self-Directed Learning Plan

<table>
<thead>
<tr>
<th>Technology:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning Goal:</strong></td>
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<tr>
<td><strong>Learning Objectives:</strong></td>
</tr>
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<table>
<thead>
<tr>
<th>Resources:</th>
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</thead>
<tbody>
<tr>
<td><strong>Learning Strategies:</strong></td>
</tr>
</tbody>
</table>

What will I do to learn this technology?

![Diagram](image)

<table>
<thead>
<tr>
<th>Due:</th>
</tr>
</thead>
</table>

How will I know when I achieve my goal?

I will share my learning with:

![Diagram](image)
This chapter reports on the results of a recent study conducted amongst eighteen K–12 teachers from Hong Kong on their experience carrying out action research on trailing technology use in the classroom when face-to-face teaching resumed after the COVID-19 pandemic. Over the course of one semester between September and December 2022, the participants introduced one or more pieces of technology in their classroom. Toward the end of the semester, they reviewed and reflected on their experience, engaged in discussions, formed a support network, and turned their research findings into learning outcomes. The teachers were then invited to take part in focus group interviews to express their views on the usefulness of engaging in action research. It was found that, overwhelmingly, all teachers were positive about conducting research specific to their own contexts and welcomed the idea of introducing action research systematically in their schools as a way to encourage staff to be reflective in the use of educational technology. The overarching aim of this chapter is to share this framework with pre-K–12 teachers so that they can engage in their own tech related action research.

INTRODUCTION

In educational technology (EdTech), despite there being much research, recommendations are rarely adopted by school teachers. McGann et al. (2020) indicate several reasons for this. First, many teachers do not have access to academic literature and, perhaps most notably, they are often too busy to follow research or try new initiatives in their specialism. There have long been calls to bridge the gap between research and practice (Norman, 2010) but the problem remains unsolved. EdTech researchers have advocated some practical initiatives, for example, appointing teachers to become instructional coaches to mentor other teachers in schools (Caneva et al., 2023) and forming a countrywide online professional community of practice (McGann et al., 2020). While these recommendations are useful, there is no mechanism for schools to encourage schools to adopt these best practices often due to a lack of funding, time, or interest. As a result, many of the ideas that get published end up being shelved rather than implemented in the classroom.

Further, in the digital age, people use technology on a daily basis. Technical competence and readiness are no longer major obstacles for teachers but to teach with technology, teachers need to be far more competent than being able to use technology. Anecdotally, when teachers were forced to teach online during the pandemic, the vast majority survived all the technical challenges imaginable (and even thrived). Some became highly motivated by technology use, exploring how different tools could be used for online teaching, creating digital learning tasks, sharing materials, and forming communities to support one another.

This chapter posits that encouraging teachers to engage in action research is an effective way to bridge the research-practice gap in educational technology. Even though teachers may be reluctant to conduct formal research due to various constraints, they generally welcome small-scale, practical research that aims to improve their current teaching practice as it is highly relevant to their context.

RESEARCH REVIEW

In order to turn an EdTech theory into practice at the school level, teachers need to examine how a particular technology is positioned in their contexts. One of the frameworks most commonly used for technology integration is Puent-
edura’s (2013) Substitution, Augmentation, Modification, and Redefinition (SAMR). Many teachers are already familiar with this model due to its widespread use in EdTech training. Here is a summary of how SAMR can be used by pre-K–12 teachers:

The table and figure below illustrate how the SAMR framework can be used to analyze the evolution of using Google Docs in the classroom in sequence. An EdTech may fit into one or more categories. Each level represents a higher level of technology integration. The substitution and augmentation levels are considered enhancement in nature, whereas the modification and redefinition levels are transformational. This model does not require effort by the teacher to revamp existing content but simply uses existing technology to push learning and student engagement to a higher level (Romrell et al., 2014).

**Figure 1**

**SAMR model (Puantedura, 2013)**

Table 1 includes an example of using SAMR to analyze using Google Docs in the classroom.

**Table 1**

<table>
<thead>
<tr>
<th>An example of SAMR analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Substitution</strong> At this level, the technology replaces a non-digital task. Students use Google Docs to replace a pen and paper peer writing task or word processing software.</td>
</tr>
<tr>
<td><strong>Augmentation</strong> Google Docs provides additional functions like multiple users sharing and editing documents.</td>
</tr>
<tr>
<td><strong>Modification</strong> Peer edit and commenting can be done either synchronously or asynchronously. Using Google Docs makes the tasks much more manageable.</td>
</tr>
<tr>
<td><strong>Redefinition</strong> Using Google Docs, students can use this tool to transform the learning experience. Teachers can also hold writer conferences online (Lin &amp; Yang, 2013).</td>
</tr>
</tbody>
</table>

An important point to note, according to Hilton (2016), is that the SAMR levels need not be hierarchical. Individuals can simply choose a level that best describes the task in question.
At this point, you might wonder why action research is particularly suited. To transform theoretical knowledge to practice, teachers must be allowed to make their own judgement and adapt theories to their own unique context. In order to do that, I argue that there is no need to reinvent the wheel, but simply incorporate a research method that most teachers are already familiar with: action research.

Let us briefly recap what action research involves. According to Dickens and Watkins (1999), action research refers to interventions that teachers introduce in order to improve their practice and evaluate the effects at the end of the process. The researcher is at the centre of the investigation. The overarching aim is to develop a fuller understanding of their practice against the backdrop of their context.

Although action research has been criticised for its lack of methodological rigor, what is paramount in this case is to turn a theory into something much more practical rather than worrying about research quality. The less formal, bottom-up nature of action research is precisely what facilitates the transformation. It decentralizes academic research and encourages teachers to take charge, thus empowering them the ability to be critical of technology use.

The chart below was developed based on observing the teacher participants of the current research study. It outlines the steps for teachers to apply action research to technology-based classroom instruction. Individual teachers can use the four-step model presented in Figure 2 to conduct their own research, or they can choose to collaborate with their colleagues.

**Figure 2**

*Four-step model to conduct technology-based action research*

---

**Step 1**

In the initial stage, teachers identify a piece of EdTech that has the potential to enhance learning and teaching. If literature is available, teachers ought to familiarize themselves with it so that their research is informed by existing studies. The theory could be, for example, the benefits of using Padlet collaboratively for social studies debates. Once the theory has been identified, teachers then take notes of these studies before proceeding to the next stage.

**Step 2**

In the second stage, teachers should critically consider how the theory is relevant to their work. They should evaluate how they can apply the theory considering factors such as student population, IT competence, age difference, time, course contents, learner motivation, equipment availability, connectivity, and security. If these factors are not an issue for the potential intervention, teachers can then start planning.
Step 3

The chosen theory does not need to be followed faithfully. If deemed appropriate, teachers can make changes as they see fit to adapt to their own unique situation. For instance, if their students are not familiar with the technology, more time can be devoted to training prior to introducing the intervention. Once ready, teachers can implement the intervention, observe, make fieldnotes, and collect data such as students’ and teachers’ feedback.

Step 4

At this stage, teachers analyze the data and reflect on the process, e.g. what went well, what did not go as planned, and what changes will be necessary moving forward. If needed, teachers can choose to repeat the cycle with modification to the original intervention and try again. The most critical step of all is to translate research results into learning outcomes. Based on the result, teachers write up learning outcomes on what students can be expected to achieve.

**IMPLICATIONS**

We will now look at a sample action research project of a high school English teacher who teaches English to Grade 11 students. A common problem the students have is organization, such as connecting ideas and being relevant when elaborating arguments. As an intervention, this teacher instructs students in one class to use *Padlet* ([https://padlet.com/](https://padlet.com/)) to plan their essays, brainstorm ideas, outline problems, and propose appropriate solutions. If necessary, a training session using *Padlet* can be offered to students. They are then asked to discuss a problem-solution essay topic on why people are not willing to exercise. Students are instructed to write their ideas on digital post-it notes and link them together in a logical sequence (see Fig 3). The intervention can be executed multiple times during the research period.

**Figure 3**

An example of students’ work on Padlet

At the end of the research, teachers should write a few learning outcomes. Below is an example of possible learning outcomes for the *Padlet* task:
Using Padlet, students will learn to:

- Explain ideas to peers clearly through a multimodal approach (using words, videos, and images)
- Reflect on and collate arguments made by others
- Organize and present arguments logically by making connections between ideas on post-it notes

Now, we will look at how teachers can use the template for EdTech adoption (see Appendix B):

1. Details and rationale for EdTech: First, write down a brief description of the EdTech you would like to explore. This will help you think about all the possibilities on how you can use it for your specialism. After that, write down the rationale for using the EdTech. Focus on the reasons why you want to use this EdTech and its advantages over traditional means. This corresponds to substitution and augmentation in SAMR.

2. Details of the action research project: Be as detailed as possible in your reflection. Think about your students: how many will participate? Are they motivated to use EdTech? What can you possibly expect them to achieve through this intervention? Are they ready to use the EdTech or do you need to train them? This will inform how you use the EdTech, which you should also write down in this section.

3. Operationalization and lesson planning: You should picture in your mind what your classroom will look like when students are using EdTech. This includes the layout, what hardware and software you need (e.g., whether enough devices are available), and what kinds of interaction will take place. Put yourself in your students’ shoes, try to think carefully about the potential issues you might encounter and solutions you can provide as a teacher. This will help you plan each lesson or activity effectively.

4. Fieldnotes and review of EdTech: Make fieldnotes as you observe what goes on throughout the research and conduct a survey at the end of the research to gather both positive and negative feedback from students. If you work with other teachers, remember to incorporate their views as well. That should give you enough data on whether you should use EdTech again and if so, any necessary changes you should make to your approach. You are now ready to write learning outcomes for the EdTech and revise your lesson plans as required.

5. Learning outcomes: Based on your observation and reflection, write 3 to 4 learning outcomes for the EdTech. Think about what students can realistically achieve. Refer to the websites in the next section for how to write effective learning outcomes.

6. Future implementation of the EdTech: decide whether to continue using the EdTech in the classroom. With input from students and teachers, note down any changes you would like to make, e.g. redesign and/or create new learning tasks. This aligns with the transformational stages of SAMR (modification and redefinition).

To conclude, this framework aimed to build on the SAMR framework for technology evaluation. Rather than adding something new, the author advocates using action research in conjunction with SAMR to bridge the research-practice gap. The template and links aim to make EdTech review as easy as possible for teachers to turn theory into research and subsequently learning outcomes for future use. Pre-K–12 teachers are particularly encouraged to adopt this model for their own technology evaluation and make amendments as they see fit.

REFERENCES


APPENDIX A: RESOURCES

Resources

Writing learning outcomes:

- [https://www.ctl.ox.ac.uk/effective-learning-outcomes](https://www.ctl.ox.ac.uk/effective-learning-outcomes)
- [https://www.colorado.edu/oda/file-program-learning-outcomes](https://www.colorado.edu/oda/file-program-learning-outcomes)

Link to action research template: [https://docs.google.com/document/d/17DILTzah4qimOzDa25eghNtpKrxwnZqC3aMajCS9qE/edit?usp=sharing](https://docs.google.com/document/d/17DILTzah4qimOzDa25eghNtpKrxwnZqC3aMajCS9qE/edit?usp=sharing)

A document on how to take fieldnotes: [https://www.westga.edu/academics/research/vrc/assets/docs/fieldnotes-script.pdf](https://www.westga.edu/academics/research/vrc/assets/docs/fieldnotes-script.pdf)
**APPENDIX B: ACTION RESEARCH TEMPLATE**

### DETAILS OF EDTECH

Name of EdTech:
Brief description of EdTech:

### RATIONALE FOR EDTECH

### DETAILS OF ACTION RESEARCH PROJECT

Duration:
Start date:
End date:
Level to trail on: Grade(s)
Number of students and teachers involved:
Number of intervention or cycle:
How will the EdTech be used:
Expected outcomes:
Readiness (teachers):
Readiness (students):

### OPERATIONALIZATION

Classroom layout:
Hardware and software required:
Other materials required:
Anticipated difficulties:
Ways to counter the difficulties:

### LESSON PLANNING

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity</th>
<th>Interactive pattern</th>
<th>Material/Aids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### FIELDNOTES

Observation:
## REVIEW OF EDTECH

| What went well:                                      |
| What did not go well:                               |
| What students liked:                                |
| What students disliked:                             |
| Teachers’ feedback:                                 |
| Other data collected:                               |

## LEARNING OUTCOMES

## FUTURE IMPLEMENTATION OF THE EDTECH

Yes/No/Maybe

Things/tasks to add/change for the future:
Interactive Teaching With Technology

DAN NIESSEN
NEO.net, USA
dniessen@neonet.org

Teachers often experience similar issues when using direct instruction. For instance, they will often only hear from confident students in class; others have difficulty assessing each student’s comprehension while teaching. Direct instruction relies on one-way communication; however, it can be supplemented with technology tools that allow for real-time engagement, progress monitoring, and immediate feedback. In other words, technology has the potential to transform teaching by making direct instruction, readings, videos, and summative assessments more interactive, engaging, and inclusive for all students. This chapter will introduce several technology tools that can enhance direct instruction, comprehension with reading and videos, and summative assessments.

INTRODUCTION

Many teachers who rely on lectures with formative knowledge checks often hear from the same handful of students. This often makes it difficult to adequately assess the understanding of every student in the class. If a teacher has 25 students in a room, they may typically only hear from the same 5 students. To reach the other 20, they may break the class into groups or have them work individually on a paper worksheet that reinforces the concepts discussed in the lecture. Since the teacher can only be in one place at a time, students who do not understand concepts could easily be missed. Depending on the amount of time left in the class period, the teacher may regroup with the whole class and review the worksheet together; or if there is too little time, they may collect all the worksheets before the period ends. Either way, the teacher is left with a stack of papers and a decision about grading for comprehension vs. completion. Moreover, students get papers handed back after grading, but there is often not enough time to reteach concepts that may have been missed. The good news is that these are common problems that can be solved with technology tools. This chapter is meant to provide teachers with specific tools and concrete examples of ways to improve such issues with direct instruction. Support is also provided for addressing problems that arise when teaching with videos, readings, and student-created projects.

RESEARCH REVIEW

This chapter is based on four main pillars of research: 1) the efficacy of direct instruction, 2) strategies for improving reading comprehension, 3) methods to improve comprehension of educational videos, and 4) the validity of creative projects in the classroom. Direct instruction has been studied for decades. For instance, Stockard et al. (2018) analyzed several different measures, found the results of direct instruction were generally positive, and concluded it was a statistically sound method of instruction. Hollingsworth and Ybarra (2017) also argued that direct instruction is a powerful and effective teaching method. In short, direct instruction is a well-established practice that teachers can and should use; however, there are modern technological tools that can supplement it.

Reading comprehension is also a well-documented but complex problem. For instance, students who read short text with strong comprehension can struggle with comprehension of longer text (Congon, 2015). Many researchers (e.g., Anggraini, 2015; Li, 2016; Najmi, 2021; Wahid & Thais, 2020) have found that formative questioning or chunking reading into smaller pieces improves reading skills or comprehension. Najmi (2021) expanded upon that concept to apply it to instructional videos, making the point that interactive elements are needed to ensure students stay on task and focus on the content. Specific technology tools can add interactivity to readings and videos.
Ngereja et al. (2020) and Cropley (2016) found that creativity through assignments like student-created projects add tremendous value to the classroom. They develop creativity skills in students, enhance motivation, and improve student learning. And there are technology tools that can be used by teachers to have students create their own engaging projects.

**IMPLICATIONS**

**Technology Supplementing Direct Instruction**

Direct instruction, often the default method for teaching, is a one-way communication process: teachers impart knowledge and students listen and take notes. However, with the integration of technology in the classroom, teachers can now make direct instruction interactive, engaging, and inclusive for all students. Making direct instruction interactive means that teachers use various tools and techniques to involve students actively in the learning process. In the past, analog methods such as class discussions, group work, and worksheets were used to supplement direct instruction. While these methods are still useful, they have some limitations that technology can help overcome.

One of the major problems with such analog methods is that it may be difficult to hear from every student. This is particularly true in large classrooms where some students may be reluctant to speak up or where time constraints may not permit all students to contribute. Additionally, it can be time-consuming to gather, analyze, or visualize data from students, especially when using paper assignments. As a result, teachers may not get immediate data on whether their students have understood the content and may not be able to adjust their instruction accordingly.

However, teachers can leverage hardware and software to make direct instruction interactive while gathering all the data they need. A full list of recommended tools is provided in Appendix A. These tools provide a range of features that allows the teacher to engage students in real-time, monitor their progress, and provide immediate feedback. However, several will be discussed in detail in this chapter, with one of the most popular being Nearpod. (See Appendix B for a direct comparison between Nearpod and another popular tool. See Appendix C for more technology tools that supplement direct instruction)

Imagine a middle school English teacher creates a slideshow presentation about literary devices like irony and flashbacks. The presentation is complete with pictures, bullet points, and even some formative questions embedded throughout the slideshow. During the lecture, the teacher asks those questions, and hears from a handful of students, but notably only a small portion of the whole class. The teacher is frustrated they put forth effort to create something that leaves them unable to gauge the understanding of the students who have not responded. They will likely need to incorporate more activities, which means more preparation and more time spent grading. Now imagine a different scenario. The same teacher uploads the same slideshow into Nearpod. All the formative questions can now be answered by all of the students at the same time, and the teacher can view their responses in real time. This in-the-moment information allows the teacher to identify specific students who will need extra support, understand if specific content points need to be retaught, or gauge if the class needs more examples. A brief tutorial is presented here for getting started with Nearpod:

1. Ensure access to a stable internet connection (Nearpod is a completely web-based tool).
2. Visit nearpod.com
3. Find and click the “Sign up for FREE” button near the top of the webpage.
4. Select the role of “Teacher.”
5. Create an account using an email address and password, a Google account, an Office 365 account, a Clever account, or a ClassLink account.
6. Once logged in, users will be greeted by the Nearpod dashboard and some on-screen tutorials.
7. On the left side of the screen are various menu options, the most important of which are:
   a. “My Lessons” is a library of lessons saved to the user’s profile.
   b. “Reports” is a database of information that was gathered from the students during lessons, mainly their responses organized into data tables and charts.
   c. “Nearpod Library” is the repository of free resources curated by Nearpod. Teachers can find hundreds of complete lessons, short activities, and video assignments - all of which are editable.
8. If a teacher wants to take an existing PowerPoint or Google Slideshow and add Nearpod interactivity to it, here are the steps:
   a. Log into Nearpod, then go to the “My Lessons” menu - nearpod.com/library
   b. Look to the center of the screen, then click the blue “Create” button.
c. Click “Lesson,” which opens the Lesson Editor.

d. Click the “Upload Files” button at the bottom of the screen.

e. Select the PowerPoint or Google Slides file from the computer’s hard drive, Google Drive, Dropbox, etc.

f. A pop-up will appear asking if you want to upload as individual slides - click the blue button titled “Individual Slides.”

g. It will take a few moments to load the slideshow into Nearpod.

h. Once it is finished uploading, click button in the upper left corner titled “Add New.”

i. Begin creating a variety of interactive elements, quizzes, games, and discussion boards.

j. The order of the activities and slides can be changed by clicking and dragging each square around the editor.

k. When finished, click “Save & Exit” at the bottom, this will take the user back to the My Lessons menu.

9. If a teacher wants to use a lesson from the pre-made Nearpod Library, follow these steps:

   a. Log into Nearpod, then go to the “Nearpod Library” menu

   b. Search by keyword at the top of the screen. For example, type the word “hurricanes.”

   c. Various pre-made activities will appear, scroll through them and click on one that looks like it may be of interest.

   d. A preview page will appear, explore each portion of the resource.

   e. If it is useful, click the “Add to My Lessons” button in the top right.

   f. If a teacher wants to edit the pre-made resource, they can do so by returning to the “My Lessons” menu and hovering their mouse over the activity, then click “edit.”

10. When a teacher has prepared a Nearpod activity and is ready for student participation, they can follow these steps:

   a. Log into Nearpod, then go to the “Nearpod Library” menu.

   b. Hover over the lesson or activity and click one of the delivery options: “Student-Paced” or “Live Participation.”

      i. Student-Paced means that students can freely move between each slide or activity in a Nearpod lesson.

      ii. Live Participation means that students cannot move freely, and the teacher decides which slide or activity students are doing at the same time.

   c. After selecting one of the delivery options, a pop-up will appear with a join code and shareable links.

   d. Give students access to the join code or link.

   e. Begin instruction, incorporating the interactive elements included in the Nearpod lesson.

   f. When the lesson is over, click the menu button in the upper left, then click “End Session.”

   g. Return to the “My Lessons” menu, then click the “Reports” menu.

   h. Click the lesson or activity of interest, then analyze or share the data Nearpod gathered.

Technology Enhancing Videos

Teachers showing videos in class or as homework often assign a paper worksheet with the video. This may lead to issues because the video may include complex content that students may not completely understand upon first viewing. The teacher may also be left with a stack of worksheets that may not accurately analyze the student understanding. With modern technology tools, teachers can add automatically graded formative knowledge checks throughout the video using websites such as Edpuzzle (see Appendix D for more interactive video tools). These websites allow teachers to select a video from their library or from YouTube and add questions at specific times. Students then watch the videos and answer questions as they go, getting feedback on each of their responses. This effectively chunks the video into smaller, more manageable segments. Edpuzzle stands out among other popular options because it can sync grades to the Google Classroom gradebook. It also has a large library of pre-made video activities. Here are some steps for getting started with Edpuzzle:

1. Ensure there is a stable internet connection, Edpuzzle is a completely web-based tool.

2. Visit edpuzzle.com
3. Find and click the “Sign up” button near the top of the webpage.
4. Select the role of “Teacher.”
5. Create an account using an email address and password, a Google account, or a Microsoft account.
6. Once logged in, the website will greet the user with the “Discover” page.
7. Use the search box at the top to enter keywords (e.g., US Constitution).
8. Several videos will appear, many of which will have questions embedded throughout the video.
9. Click on one of the videos, and a preview page will appear.
10. Examine the video and each question.
11. If the video is suitable for class, click “Assign” at the top of the webpage and make it available to students.
12. If changes need to be made to the questions, or if the video needs to be trimmed, click “Edit” at the top of the webpage.
13. The editor allows teachers to trim out parts of the video and edit the questions that appear.
14. Rosters of students can be added to an Edpuzzle account by returning to the “Discover” homepage, then clicking the small “+” next to the menu titled “My Classes.”
15. Grades can be synced between Edpuzzle and an LMS like Google Classroom by clicking on the name of the class under “My Classes”, then clicking the assignment, then looking to the bottom right and clicking “Update on Google Classroom.”

Technology Enhancing Reading - Chunking & Formative Questions

Reading activities are not often thought of as opportunities for much technology integration. But when students are tasked with a reading assignment, they can easily become lost or overwhelmed by longer text. Chunking reading content into smaller segments and asking formative questions throughout can help improve comprehension (Wahid & Thais, 2020). CommonLit is a completely free website that has thousands of reading articles with pre-made questions that automatically chunk the reading into smaller pieces (see Appendix E for more options and details).

For example, a teacher creates a lesson plan focusing on the sharecropping system in America after the Civil War. They decide they want to incorporate some primary source reading documents. With a tool like CommonLit, they can easily find such a resource with the added bonus of pre-made formative questions. One such example would be Henry Adams' Testimony Before Congress, easily accessible on CommonLit. In this activity, students read chunks of the full text before being presented with a formative guiding question after each chunk. All the questions are pre-made, automatically graded, and the student responses are visible to the teacher through their dashboard. Teachers can clearly benefit from the time savings, and students can benefit from the quality reading materials that are chunked into small segments.

Here are some steps for getting started with CommonLit:

1. A stable internet connection is recommended, the bulk of CommonLit is web-based. However, teachers have the option of printing the readings and questions.
2. Visit commonlit.org
3. Click “Sign up” near the top right corner.
4. Select the option: “I am an educator”, then fill out the questionnaire, then create a login with an email address, a Google account, or a Clever account.
5. Once logged in, explore the “Browse Content” menu, filter by grade level, Lexile range, Genre, etc. There is also a keyword search at the top, for example search for the term “alliteration.”
6. Many search results will appear, most of which will include the reading material, a teacher overview with some tips, guiding questions that chunk the text, assessment questions that serve as a summative assessment, and discussion questions.
7. After finding a reading assignment suitable for the class, click the “Assign” button in the upper left corner. Alternatively, teachers may print the reading and questions by clicking “Download PDF” next to the “Assign” button.
8. Teachers can import a roster of students from Google Classroom by following these steps:
   a. Click on the profile icon in the upper right corner
   b. Under “Manage Classes”, find “Create a Class”
   c. Select “Import”, then “Import from Google Classroom”
Technology Enhancing Reading - Accessibility

The term Accessibility can mean different things to different teachers. It may mean helping English Language Learners (ELL) or students with disabilities to read. It could entail providing students who struggle with comprehension multiple opportunities to learn content. Or it may mean allowing students to demonstrate their understanding in non-traditional ways (New EdTech Classroom, 2021). When it comes to reading, technology tools such as Immersive Reader can help struggling students through text-to-speech, visual enhancements, translation, and picture dictionaries (see Appendix E for more assistive reading tools and their features, particularly for teachers without access to Microsoft and/or Microsoft Word).

Take the example of an ELL student who can understand some English but is much more fluent in their native language. If the teacher presents them with a reading material in English, their comprehension will be a fraction of what it would be if it were translated into their native language. If the teacher provides the reading inside of Microsoft Word, they can use the Immersive Reader tool. It allows the student to translate the entire text, and the program will read it aloud in English and many other languages. Immersive Reader also includes a picture dictionary, so if the student comes across a word in English they do not recognize, they can click on it and see an image that matches. They can also hear the pronunciation of a word in English and their language. For instance, if a Spanish-speaking student clicks on the word “school” Immersive Reader will display it as “escuela” and show images of a school, along with an option to hear how the word is pronounced in both languages.

Immersive Reader appears across several of the Microsoft Office applications. However, the following steps provide information getting started with Immersive Reader in Microsoft Word:

1. Ensure access to Microsoft Word.
2. Create a new blank Word Document.
3. Type or paste text that students are going to be tasked with reading.
4. Click the “Share” button in the top right corner, then send students the document using the Share Menu.
5. On the student’s device, open the Word Document.
6. Instruct the student to click the “Immersive Reader” button near the top of the screen. Depending on sharing settings, it may be found under the “View menu.”
7. The reading will then open inside of Immersive Reader. Here are some key features:
   a. Click the play button at the bottom to start text-to-speech
   b. The double “A” symbol at the top will adjust the viewing experience
   c. The book icon in the top right corner provides accommodation features like translation and the picture dictionary

Accommodation Through Video

Accessibility does not begin or end with reading accommodations like those possible in Immersive Reader. Giving students multiple opportunities to learn the content is crucial to ensuring they understand the material. Short instructional videos created with screen recorders like Loom, used in conjunction with lecture slideshows or a demonstration on an online whiteboard like Jamboard, can eventually leave students with a library of help videos posted to the teacher’s YouTube channel, Google Classroom, or other LMS. (See more about screen recorders and online whiteboards in Appendices F and G.)

Having this library of help videos available inherently increases accessibility because students can rewind the videos and watch them as many times as they need. In addition, virtually every video posted to YouTube comes with automatically generated closed captions that can be translated into a variety of languages. The Google Chrome browser also has a feature called Live Captions that provides closed captions on any audio source in the browser for both audio and video files. This means if the teacher shows a YouTube video in class, they can use translated captions inside the YouTube video to accommodate the ELL students, while using Live Captions to display closed captioning in English.

Here are the steps teachers can take to create short instructional videos of an online whiteboard demonstration:

1. Sign up for a free education account for the Loom screen recorder at Loom.com/education
2. Install the Loom Chrome Browser Extension at this link
3. Open Google Jamboard at jamboard.google.com. See Appendix G for more information about Jamboard
4. Click the Loom Chrome extension icon and begin recording the screen, microphone, and webcam
5. Begin teaching as if speaking directly to students, including demonstrations, images, and explanations
6. When finished, click the Loom Chrome extension icon again, and stop recording
7. A new browser tab will open, with the option to copy a shareable link or download the video
8. Copy the shareable link or upload the video to Google Classroom, LMS, or another easily accessible location for students to watch

Technology Enhancing Student-Created Projects

Last, but not least, teachers can enhance their instruction (and accessibility) through student created projects, something at the top of Bloom’s taxonomy (Armstrong, 2010). This approach allows students to showcase their skills and knowledge in a way that suits their learning style, instead of forcing all students into the lecture-worksheet-quiz-test model. Creative assessments come in many forms: video projects, presentations, websites, eBooks, 3D models, etc. (See Appendix H for more technology tools suited for student-created projects; see appendix I for videos related to broader use of all tools.)

Canva (in particular) stands out among other technology tools in this category because of its flexibility and emphasis on creativity. Its editor allows students to make websites, slideshows, infographics, videos, and recordings of themselves or their computer screens. Canva allows them to combine images, graphics, photos, videos, and music, which incorporates creativity and choice into a student-created project. Imagine elementary students creating a short informational video about ecosystems and their characteristics, complete with engaging visuals and music. The content added to the video could be the same as it would be on a summative test, but in this format, it becomes more engaging and memorable for students. These sorts of student-created projects are excellent supplements or replacements for traditional summative assessments. Here are some steps for getting started with using Canva in class:

1. Ensure there is a stable internet connection, Canva is an online web tool. See Appendix H for more details
2. Sign up for the free education version of Canva at Canva.com/education
3. Once logged in with an Education account, click “Invite Members” in the lower left corner.
4. Copy the “Share Link” in the upper right section of the pop-up menu and send it to students.
5. When students go to that link, they will automatically appear in the teacher’s Canva class.
6. The teacher has the option to create a template for students or allow them to create something completely on their own.
   a. If the teacher wants students to begin with a template, they can make any kind of design, then while in the Canva editor, click “Share” in the top right, then click “Assignment.”
   b. Each student will then have a copy of the template.
   c. When students are finished with their designs, they will click the button titled “Send to teacher” in the top right corner of the screen when they are editing their version of the template.
   d. The teacher can view all of the students’ submissions inside the “Classwork” menu on the left side of the Canva homepage.
7. Encourage students to be creative and give them choice for their project, whether they create an infographic, a slideshow, a video, a website, or another type of design.
**REFERENCES**


Wahid, J. H., & Thais, I. A. (2020). Chunking strategy; In enhancing fourth semester students’ reading skill at English department of Muhammadiyah University. *Jo-ELT (Journal of English Language Teaching)*, 7(1), 18–25. [https://doi.org/10.33394/jo-elt.v7i1.2636](https://doi.org/10.33394/jo-elt.v7i1.2636)
### APPENDIX A:

**Summary of Popular EdTech Tools**

ChatGPT assisted with the creation of this table. Here is the prompt:

“I’m going to give you a list of educational technology tools. Create a table with the following information in each column: **Column 1** - Name of the tool, **Column 2** - url/web address, **Column 3** - short summary of what that EdTech tool does, **Column 4** - that tool’s pricing (is it free, or how much the different versions cost?)”

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Summary</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actively Learn</td>
<td>Actively Learn is an online literacy platform that provides teachers and students with access to a vast library of texts, customizable assignments, and interactive features to enhance reading comprehension and critical thinking skills.</td>
<td>Free and paid versions available. More details at <a href="http://active-lylearn.com/plans">active-lylearn.com/plans</a></td>
</tr>
<tr>
<td>Book Creator</td>
<td>Book Creator is a simple and versatile tool that allows educators and students to create and publish their own digital books with images, videos, and audio recordings.</td>
<td>Free and paid versions available. More details at <a href="http://bookcreator.com/pricing">bookcreator.com/pricing</a></td>
</tr>
<tr>
<td>Canva</td>
<td>Canva is a graphic design platform that offers a variety of templates, stock images, and design tools to create posters, flyers, infographics, and other visual materials for educational purposes.</td>
<td>Free version available for educators. More details at <a href="http://canva.com/education">canva.com/education</a></td>
</tr>
<tr>
<td>Clipchamp</td>
<td>Clipchamp is a video creation and editing tool that enables teachers and students to make professional-quality videos for online learning, presentations, and assignments.</td>
<td>Free and paid versions available. More details at <a href="http://clipchamp.com/pricing">clipchamp.com/pricing</a></td>
</tr>
<tr>
<td>CommonLit</td>
<td>CommonLit is a free digital platform that provides teachers and students with access to high-quality reading materials, assessments, and progress tracking tools to support literacy development across multiple subjects.</td>
<td>Free for teachers and students</td>
</tr>
<tr>
<td>Edpuzzle</td>
<td>Edpuzzle is an interactive video platform that allows teachers to create custom video lessons, add questions and annotations, and monitor student progress and engagement.</td>
<td>Free and paid versions available. More details at <a href="http://edpuzzle.com/pricing">edpuzzle.com/pricing</a></td>
</tr>
<tr>
<td>Google Docs</td>
<td>Google Docs is a cloud-based word processor that enables collaborative writing, editing, and sharing of documents in real-time.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Google Forms</td>
<td>Google Forms is a web-based survey tool that allows teachers and students to create and distribute online quizzes, assessments, and feedback forms.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Google Sites</td>
<td>Google Sites is a web design tool that enables educators and students to create and publish their own websites with customizable templates and drag-and-drop features.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Immersive Reader</td>
<td>Immersive Reader is a free accessibility tool that helps students with learning differences to read and understand digital texts by providing features such as text-to-speech, font and spacing customization, and picture dictionaries.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>EdTech Tool</td>
<td>Summary</td>
<td>Pricing</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>iMovie</td>
<td>iMovie is a video editing software for Mac and iOS devices that allows teachers and students to create and edit high-quality videos with special effects, music, and soundtracks.</td>
<td>Free for Mac and iOS devices</td>
</tr>
<tr>
<td>InsertLearning</td>
<td>Insert Learning is a Chrome extension that allows teachers to turn any web page into an interactive lesson by adding notes, questions, and multimedia content that students can engage with and respond to.</td>
<td>Free and paid versions available. More details at <a href="https://insertlearning.com/pricing">insertlearning.com/pricing</a></td>
</tr>
<tr>
<td>Jamboard</td>
<td>Jamboard is a digital whiteboard tool that allows educators and students to collaborate and brainstorm ideas in real-time, and add images, sticky notes, and drawings.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Loom</td>
<td>Loom is a screen and video recording software that enables teachers and students to create and share video messages, tutorials, and presentations.</td>
<td>Free version available for educators. More details at <a href="https://loom.com/education">loom.com/education</a></td>
</tr>
<tr>
<td>Nearpod</td>
<td>Nearpod is an interactive presentation and assessment platform that allows educators to create and deliver engaging lessons with multimedia content, quizzes, and polls.</td>
<td>Free and paid versions available. More details at <a href="https://nearpod.com/pricing">nearpod.com/pricing</a></td>
</tr>
<tr>
<td>OrbitNote</td>
<td>OrbitNote allows teachers to transform how they use documents in the classroom. They can create an accessible, dynamic and collaborative space that works for everyone. This includes uploading a paper document and transforming it into an interactive PDF file or using Orbit Note’s powerful accessibility tools to accommodate every student’s needs.</td>
<td>Free and paid versions available. More details at <a href="https://texthelp.com/pricing">texthelp.com/pricing</a></td>
</tr>
<tr>
<td>Pear Deck</td>
<td>Pear Deck is a presentation platform that allows educators to create interactive and engaging lessons with questions, polls, and drawing activities that students can respond to in real-time.</td>
<td>Free and paid versions available. More details at <a href="https://peardeck.com/pricing">peardeck.com/pricing</a></td>
</tr>
<tr>
<td>PlayPosit</td>
<td>Playposit is an interactive video platform that allows educators to create custom video lessons, add questions and annotations, and monitor student progress and engagement.</td>
<td>Free and paid versions available. More details at <a href="https://go.playposit.com/pricing-overview">go.playposit.com/pricing-overview</a></td>
</tr>
<tr>
<td>Read&amp;Write</td>
<td>Read&amp;Write is a literacy support tool that offers help with everyday tasks like reading text out loud, understanding unfamiliar words, researching assignments and proofing written work. It is particularly useful because it brings these features into the Google apps like Google Docs and Slides.</td>
<td>Free and paid versions available. More details at <a href="https://texthelp.com/pricing">texthelp.com/pricing</a></td>
</tr>
<tr>
<td>Rewordify</td>
<td>Rewordify is a web-based tool that helps students to understand complex texts by simplifying the vocabulary and structure of the text while maintaining the original meaning.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Screencastify</td>
<td>Screencastify is a screen recording software that enables educators and students to create and share video tutorials, demonstrations, and presentations.</td>
<td>Free and paid versions available. More details at <a href="https://screencastify.com/pricing">screencastify.com/pricing</a></td>
</tr>
<tr>
<td>EdTech Tool</td>
<td>Summary</td>
<td>Pricing</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>TeacherMade</td>
<td>TeacherMade is an online platform that allows teachers to create interactive and personalized digital assignments with multiple question types, and automated grading and feedback.</td>
<td>Free and paid versions available. More details at teacher-made.com/plan</td>
</tr>
<tr>
<td>Tinkercad</td>
<td>Tinkercad is a web-based 3D modeling tool that allows students to design and create their own digital models, and learn about geometry, engineering, and coding.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>WeVideo</td>
<td>WeVideo is a cloud-based video editing platform that enables educators and students to create and edit high-quality videos with customizable templates, special effects, and collaboration features.</td>
<td>Paid versions available. More details at wevideo.com/pricing</td>
</tr>
<tr>
<td>Whiteboard.fi</td>
<td>Whiteboard.fi is a virtual whiteboard tool that allows educators to create and share interactive whiteboards with individuals or groups of students and monitor their progress and participation.</td>
<td>Free and paid versions available. More details at whiteboard.fi/#pricing</td>
</tr>
</tbody>
</table>
APPENDIX B

Nearpod vs Pear Deck Features

<table>
<thead>
<tr>
<th>Nearpod</th>
<th>Common Features</th>
<th>Pear Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premade lesson library contains many subject areas</td>
<td>Free and Paid versions</td>
<td>Students must log in with their Google accounts to do activity</td>
</tr>
<tr>
<td>Includes interactive videos (like Edpuzzle)</td>
<td>Use existing Google Slides or PowerPoints</td>
<td>Premade lesson library has lesson from other organizations like PBS Newshour, Newsela, Flipgrid, and EverFi</td>
</tr>
<tr>
<td>Has more question types than Pear Deck</td>
<td>Gather reports to analyze data</td>
<td></td>
</tr>
<tr>
<td>Students simply type their name when joining activity</td>
<td>See formative data in the moment</td>
<td>Free version allows you to add interactivity directly in Google Slides</td>
</tr>
</tbody>
</table>
**APPENDIX C**

**Direct Instruction Tech Tools**

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Summary</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentimeter</td>
<td>Test knowledge, start discussions, and give students the chance to ask you the right questions at the right time. Mentimeter is an audience engagement platform with a wide array of features like Dynamic Word Clouds, Live &amp; Instant Polling, Entertaining Quizzes, Informative Q&amp;As, and Insightful Surveys. This program integrates with PowerPoint, Google Slides, Zoom, Google Meet, and more.</td>
<td>Teachers can use the free Education version, with an option to upgrade for additional features. More information at - <a href="https://www.mentimeter.com/plans/education">https://www.mentimeter.com/plans/education</a></td>
</tr>
<tr>
<td>Nearpod</td>
<td>Nearpod is an interactive presentation and assessment platform that allows educators to create and deliver engaging lessons with multimedia content, quizzes, and polls. Nearpod allows teachers to upload their own PowerPoint and Google Slides presentations.</td>
<td>Teachers can use the free Education version, with an option to upgrade for additional features. More information at - <a href="https://nearpod.com/pricing">https://nearpod.com/pricing</a></td>
</tr>
<tr>
<td>Pear Deck</td>
<td>Pear Deck is a presentation platform that allows educators to create interactive and engaging lessons with questions, polls, and drawing activities that students can respond to in real-time. Pear Deck integrates with PowerPoint at Google Slides.</td>
<td>Teachers can use the free Education version, with an option to upgrade for additional features. More information at - <a href="https://www.peardeck.com/pricing">https://www.peardeck.com/pricing</a></td>
</tr>
<tr>
<td>Poll Everywhere</td>
<td>Poll Everywhere gives each student a discreet way to voice their opinions and comprehension. Use interactive questions to gauge understanding and adjust your lecture based on feedback from the entire room. Students respond simultaneously from the privacy of their tablets or other devices. Since feedback is anonymous, everyone can focus on what is said rather than who said it. All students have an equal opportunity to be heard. Poll Everywhere integrates with PowerPoint at Google Slides.</td>
<td>Teachers can use the free Education version, with an option to upgrade for additional features. More information at - <a href="https://www.polleverywhere.com/plans/k-12">https://www.polleverywhere.com/plans/k-12</a></td>
</tr>
<tr>
<td>Slido</td>
<td>Use live polls or quizzes to check if your students are keeping up with the lecture. This will help you identify the points that need clarification and adjust your lesson accordingly. Remove students’ fear of asking questions in front of the class. With Slido, they can post questions anonymously from their phones and upvote the questions they like. Slido integrates with PowerPoint and Google Slides.</td>
<td>Teachers can use the free Education version, with an option to upgrade for additional features. More information at - <a href="https://www.slido.com/pricing">https://www.slido.com/pricing</a></td>
</tr>
</tbody>
</table>
## APPENDIX D

### Video Tech Tools

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Summary</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Edpuzzle</strong></td>
<td>Edpuzzle is an interactive video platform that allows teachers to create custom video lessons, add questions and annotations, and monitor student progress and engagement.</td>
<td>Free and paid versions available. More details at edpuzzle.com/pricing</td>
</tr>
<tr>
<td><strong>Nearpod</strong></td>
<td>Nearpod is an interactive presentation and assessment platform that allows educators to create and deliver engaging lessons with multimedia content, quizzes, and polls. One of its activity types is an interactive video that requires students to watch a video and answer formative questions placed strategically throughout the video.</td>
<td>Free and paid versions available. More details at nearpod.com/pricing</td>
</tr>
<tr>
<td><strong>PlayPosit</strong></td>
<td>Playposit is an interactive video platform that allows educators to create custom video lessons, add questions and annotations, and monitor student progress and engagement.</td>
<td>Free and paid versions available. More details at go.playposit.com/pricing-overview</td>
</tr>
</tbody>
</table>
## APPENDIX E

### Reading Tech Tools

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Primary Purpose</th>
<th>Summary</th>
<th>Examples/More Information</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actively Learn</td>
<td>Reading Comprehension</td>
<td>Actively Learn is an online literacy platform that provides teachers and students with access to a vast library of texts, customizable assignments, and interactive features to enhance reading comprehension and critical thinking skills. This tool splits the text into smaller pieces and asks formative questions throughout the reading.</td>
<td>How Do Tornadoes Look on the Inside?</td>
<td>Free and paid versions available. More details at activelylearn.com/plans</td>
</tr>
<tr>
<td>CommonLit</td>
<td>Reading Comprehension</td>
<td>CommonLit is a free digital platform that provides teachers and students with access to high-quality reading materials, assessments, and progress tracking tools to support literacy development across multiple subjects. This tool splits the text into smaller pieces and asks formative questions throughout the reading.</td>
<td>Henry Adams’ Testimony Before Congress</td>
<td>Free for teachers and students</td>
</tr>
<tr>
<td>Immersive Reader</td>
<td>Reading Assistance</td>
<td>Immersive Reader is a free accessibility tool that helps students with learning differences to read and understand digital texts by providing features such as text-to-speech, font and spacing customization, and picture dictionaries.</td>
<td>Immersive Reader can be found in Microsoft Word, OneNote, Outlook, and other Microsoft tools. It is also integrated into other technology tools. See the entire list here.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td>Insert Learning</td>
<td>Reading Comprehension</td>
<td>Insert Learning is a Chrome extension that allows teachers to turn any web page into an interactive lesson by adding notes, questions, and multimedia content that students can engage with and respond to. This tool allows teachers to split the text into smaller pieces and ask formative questions throughout the reading.</td>
<td>See examples and how to get started on their website.</td>
<td>Free and paid versions available. More details at insertlearning.com/pricing</td>
</tr>
<tr>
<td>OrbitNote</td>
<td>Reading Assistance</td>
<td>OrbitNote allows teachers to transform how they use documents in the classroom. They can create an accessible, dynamic and collaborative space that works for everyone. This includes uploading a paper document and transforming it into an interactive PDF file or using Orbit Note’s powerful accessibility tools to accommodate every student’s needs.</td>
<td>DitchThatTextbook.com wrote an excellent blog post about using Orbit Note. See Orbit Note’s website for more examples and how to get started.</td>
<td>Free and paid versions available. More details at texthelp.com/pricing</td>
</tr>
<tr>
<td>EdTech Tool</td>
<td>Primary Purpose</td>
<td>Summary</td>
<td>Examples/More Information</td>
<td>Pricing</td>
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</tr>
<tr>
<td><strong>Read&amp;Write</strong></td>
<td>Reading Assistance</td>
<td>Read&amp;Write is a literacy support tool that offers help with everyday tasks like reading text out loud, understanding unfamiliar words, researching assignments and proofing written work. It is particularly useful because it brings these features into the Google apps like Google Docs and Slides.</td>
<td>See examples and how to get started on their website.</td>
<td>Free and paid versions available. More details at texthelp.com/pricing</td>
</tr>
<tr>
<td><strong>Rewordify</strong></td>
<td>Reading Assistance</td>
<td>Rewordify is a web-based tool that helps students to understand complex texts by simplifying the vocabulary and structure of the text while maintaining the original meaning. Rewordify also has a section with public domain reading materials, including classic literature and important documents.</td>
<td>An online demonstration can be completed here. Rewordify’s version of <em>The Declaration of Independence</em>. Rewordify’s version of <em>Alice’s Adventures in Wonderland</em>.</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td><strong>Teacher-Made</strong></td>
<td>Reading Comprehension</td>
<td>TeacherMade is an online platform that allows teachers to create interactive and personalized digital assignments with multiple question types, and automated grading and feedback. Unlike CommonLit or Actively Learn, this tool allows teachers to upload their own reading materials.</td>
<td>10 Ways to use Teacher Made</td>
<td>Free and paid versions available. More details at teachermade.com/plan</td>
</tr>
</tbody>
</table>
## APPENDIX F

### Screen Recorders

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Summary</th>
<th>Examples/More Information</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chromebook Screencast</strong></td>
<td>The Screencast app is available on all ChromeOS devices with Chrome version 103 or later. This app allows teachers to record instructional videos, live classes, feedback videos, and more. Each video will automatically come with transcription and translation features. The videos are automatically uploaded to the user’s Google Drive, and there are no time limits for the recordings.</td>
<td>This help page from Google explains how to get started</td>
<td>Free for personal and educational use</td>
</tr>
<tr>
<td><strong>Loom</strong></td>
<td>Loom is a screen and video recording software that enables teachers and students to create and share video messages, tutorials, and presentations.</td>
<td></td>
<td>Free version available for educators. More details at loom.com/education</td>
</tr>
<tr>
<td><strong>Screencastify</strong></td>
<td>Screencastify is a screen recording software that enables educators and students to create and share video tutorials, demonstrations, and presentations.</td>
<td>Screencastify integrates seamlessly with Google Classroom and features an interactive question feature similar to Edpuzzle. Learn more about features here</td>
<td>Free and paid versions available. More details at screencastify.com/pricing</td>
</tr>
<tr>
<td><strong>ScreenPal</strong></td>
<td>ScreenPal is the new name for Screencast-o-matic. This video screen recorder includes the capability to edit videos and screenshots, add annotations, and unlimited video creation.</td>
<td>The free version allows unlimited recordings, each up to 15 minutes long, and several basic video editing features. Learn more about features here.</td>
<td>Free and paid versions available. More details at <a href="https://screenpal.com/plans/education/">https://screenpal.com/plans/education/</a></td>
</tr>
</tbody>
</table>
## Online Whiteboards

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Summary</th>
<th>Examples/More Information</th>
<th>Pricing</th>
</tr>
</thead>
</table>
| Explain Everything | This online visual tutorial app allows teachers to use a variety of tools to easily explain any concept. Teachers can create engaging and helpful visuals so students can truly understand key concepts. This app includes a built-in screen recorder that allows teachers to instantly record and share helpful videos for their students. | Whiteboarding  
Explainer Videos  
| Jamboard        | Jamboard is a digital whiteboard tool that allows educators and students to collaborate and brainstorm ideas in real-time, and add images, sticky notes, and drawings.                                      | This tutorial video explains how to use Jamboard                 | Free for personal and educational use                                                        |
| Whiteboard.fi   | Whiteboard.fi is a virtual whiteboard tool that allows educators to create and share interactive whiteboards with individuals or groups of students and monitor their progress and participation.          | 5 Ways to Use Whiteboard.fi in the Classroom                    | Free and paid versions available. More details at [whiteboard.fi/#pricing](whiteboard.fi/#pricing) |
## Student Project Tech Tools

<table>
<thead>
<tr>
<th>EdTech Tool</th>
<th>Primary Purpose</th>
<th>Summary</th>
<th>Examples/More Information</th>
<th>Pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adobe Express</td>
<td>Multimedia Designs</td>
<td>Adobe Express for Education allows teachers and students to create many kinds of engaging visual products. Students can demonstrate what they have learned through presentations, images, animations, websites, and videos. Students' accounts will come with thousands of templates, free stock images and videos, and it can be used on Chromebooks or iPads.</td>
<td>Any K–12 certified educator in the US with a Google Workspace for Education account is eligible for this program. More information can be found <a href="#">here</a></td>
<td>Free for US Educators</td>
</tr>
<tr>
<td>Book Creator</td>
<td>eBook Creation</td>
<td>Book Creator is a simple and versatile tool that allows educators and students to create and publish their own digital books with images, videos, and audio recordings.</td>
<td><a href="#">This Pinterest list</a> from Book Creator features over 300 examples of student-created eBooks</td>
<td>Free and paid versions available. More details at <a href="#">bookcreator.com/pricing</a></td>
</tr>
<tr>
<td>Canva</td>
<td>Multimedia Designs</td>
<td>Canva is a graphic design platform that offers a variety of templates, stock images, and design tools to create posters, flyers, infographics, and other visual materials for educational purposes.</td>
<td><a href="#">10 ways to take your lessons to the next level with Canva</a></td>
<td>Free and paid versions available. More details at <a href="#">canva.com/pricing</a></td>
</tr>
<tr>
<td>Clipchamp</td>
<td>Video Editing</td>
<td>ClipChamp is a video creation and editing tool that enables teachers and students to make professional-quality videos for online learning, presentations, and assignments.</td>
<td>Learn how to get started on <a href="#">Clip Champ’s Training Center</a></td>
<td>Free and paid versions available. More details at <a href="#">clipchamp.com/pricing</a></td>
</tr>
<tr>
<td>Google Earth</td>
<td>Virtual Tours</td>
<td>Google Earth has a feature called Projects that allows teachers and students to create their own Virtual Tours. Students can search for location, then add it to their tour, including elements such as descriptions, images, and links. When students are finished, they can share their Virtual Tours with each other or the teacher.</td>
<td>Professionally made Virtual Tours can be found under the “Voyager” section in Google Earth</td>
<td>Free for personal and educational use.</td>
</tr>
<tr>
<td>Google Sites</td>
<td>Website Creation</td>
<td>Google Sites is a web design tool that enables educators and students to create and publish their own websites with customizable templates and drag-and-drop features.</td>
<td><a href="#">DitchThatTextbook.com</a> wrote an excellent article with 20 tips and tricks for using Google Sites in the Classroom</td>
<td>Free for personal and educational use.</td>
</tr>
<tr>
<td>iMovie</td>
<td>Video Editing</td>
<td>iMovie is a video editing software for Mac and iOS devices that allows teachers and students to create and edit high-quality videos with special effects, music, and soundtracks.</td>
<td><a href="#">The University of Southern Florida</a> wrote an article with 5 examples of using iMovie in the classroom</td>
<td>Free for Mac and iOS devices</td>
</tr>
<tr>
<td>Tinkercad</td>
<td>3D Model Design</td>
<td>Tinkercad is a web-based 3D modeling tool that allows students to design and create their own digital models, and learn about geometry, engineering, and coding.</td>
<td><a href="#">Tinkercad has a library of lesson plans</a> that are free and available to anyone</td>
<td>Free for personal and educational use.</td>
</tr>
<tr>
<td>WeVideo</td>
<td>Video Editing</td>
<td>WeVideo is a cloud-based video editing platform that enables educators and students to create and edit high-quality videos with customizable templates, special effects, and collaboration features.</td>
<td><a href="#">5 Activities to Jump-Start Your WeVideo Classroom</a></td>
<td>Paid versions available. More details at <a href="#">wevideo.com/pricing</a></td>
</tr>
</tbody>
</table>
Using Technology To Effectively Improve Formative Assessments

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The topic of this review is understanding the current uses and implementations of technology within formative assessment. Studies were analyzed to find that a proven effective tool for teaching, formative assessment, benefited greatly from a synthesis of technology. Current methodology and some physical tools being used in classrooms were both examined. Review of existing literature supports the practical application of implementing technology into formative assessments. Evidence exists to show improvement in experience and performance when formative assessment is conducted through/with the use of technology. Practical recommendations for the reader on this topic revolve around synthesizing technology into their classrooms. This review will serve to provide evidence of the benefits that technology integration offers teachers and students in the realm of formative assessment. Upon conclusion, the reader will leave this chapter with a clearer understanding of how technology can support formative assessment.

INTRODUCTION

Formative assessment is a common part of the learning process that every teacher is accustomed to. As educators, we teach students, we assess students, and then we analyze those results to find if learning took place. In classrooms of the past, the best way to get this information was to have students submit work samples, or by assessing students verbally as the instructor. This was a time consuming and challenging process. With the path of development technology has followed, this burden has been eased for teachers.

Presently, there are numerous options for teachers to conduct formative assessments, and not be left with stacks of papers to grade. (Bennett & Cunningham, 2009; Crompton & Keane, 2012) One of the greatest perks that technology has to offer to teachers is the easing of data collection. Technology-based assessments gather data instantly, and present it to educators in a format that allows them to spend time planning next steps, not figuring out where everyone is.

As research continues to support the positive effect of high-fidelity formative assessment (Voineau, 2018), teachers should understand both the importance of formative assessments, and how to use technology to streamline its use in the classroom. Effective teaching comes from understanding your student needs, and there is no better way to provide data for those academic needs than through the immediate results you receive with formative assessments. Learning how to fast track that process, and make it work in your favor, is what makes a teacher move beyond effective, into fantastic.

RESEARCH REVIEW

To better understand what value formative assessment has and how technology improves it, literature has been reviewed to provide you with appropriate evidence. The first piece of evidence tells us that formative assessment improves not only a learner’s language, but also the instructors’ ability to identify needs and teach to them (Alzaid & Alkarzae, 2019). Following that, Tran and Ma (2021) wrote about the benefits of online formative assessment. A key finding for them was that immediate feedback and engaging content were promoted with online assessments, and were deemed critical to learning processes. An article by Tomasik et al. (2018) examining computer-based tools found an increased en-
hancement in availability, flexibility, and versatility of data available to teachers, and learning opportunities available to students.

Looking into the use of devices in the classroom, research was found that supported students using hand-held devices in the classroom. Students were given hand-held clickers to answer an online assessment, and results were sent to the teacher immediately. Of the two groups surveyed, they both showed improved engagement and enjoyment in the lesson. The teacher surveyed expressed happiness to have organized data so readily available (Bennett & Cunningham, 2009). Another research study looked at students using iPod touches in a similar manner. Overall, findings indicated that the use of technology improved student engagement and increased understanding of key concepts (Crompton & Keane, 2012).

IMPLICATIONS

What is most important about this work is twofold. First, teachers must understand how impactful and essential formative assessment is to the learning process. We figure out what students know, and more importantly, what they do not know. Then we can take that information, and reconfigure our delivery of content to those students. Meeting students at their current level is crucial to impactful learning, and formative assessment is how you find that level.

Differentiation in learning is a concept that most teachers should know by now. No two students that come through your door will be the same. Each student will bring with them a unique personality, learning style, and achievement level. It is our job to take the content we need to provide, and adapt it and stretch it to ensure every student can retain and absorb that information. Teachers who take the time to differentiate learning are the teachers who reach all of their students. And, oftentimes, do not have to reteach missed content. Teach it effectively the first time, not the second, third, or fourth!

There are many programs that can assist in differentiated learning. Consider starting by pointing readers towards some of the programs that implement a learning path style program. Some of these programs include ExactPath, iReady, Prodigy, and ClassCraft (See Appendix A for an overview and Appendix B for related tutorials).

ExactPath and iReady are similar programs that start by implementing a diagnostic assessment. These assessments are scaling tests that adapt to the student’s performance mid-test taking. They are designed to gather data on student performance in the main domains in the subjects of math and reading, and identify areas of strength and weakness. Upon completion of this diagnostic assessment, students are placed on their “path”. The path works by providing students with interactive assignments suited to address their identified weaknesses. Interactive mini-lessons start each assignment, followed by student practice in the content. What makes these programs so effective is how you can have 25 students all on it, and 25 different lessons can be occurring. Technology here helps to maximize content coverage in the classroom.

The next tool discussed is similar to the first two, but it adds an element of gamification of learning to it. Prodigy is a math based differentiated learning program that gives students an avatar, and puts them in a magical world. Students explore this magical world, completing quests, collecting gear and pets, and entering turn-based combat situations. The combat is resolved by students answering math questions to attack enemies. The questions start with a base level diagnostic assessment, and establish a level of strength and weakness for each student. Questions are then differentiated and given based on those strengths and weaknesses. The huge draw this game has over the previous two learning tools is the game element. Students can spend hours immersed in an actual full game, and be learning and solving math problems that entire time!

Finally, there is a program called ClassCraft. ClassCraft continues the gaming element with learning, but the gaming takes a more passive approach. Students are not doing turn-based combat in this game, but rather are completing assigned work as normal. Students still receive an avatar, and collect gear and pets, but they do not directly fight with them. Instead, they gain experience points to level up, and collect “powers” that they can use in the classroom for real-life rewards. The rewards can be anything the teacher wants, and include some examples such as: a 10 minute break from work, listening to music while working, getting a snack, working with a friend. This tangible reward system gives students a gamified avatar to work with, while also providing real-life rewards to work for.

The most effective way to use this tool is to use the motivational aspect of it by assigning your work through the user interface of ClassCraft. Let’s say you are going to give your students a lesson on multiplication, and then have them watch an EdPuzzle for follow up, and complete independent practice. You can take those same steps of the lesson, and create a path in the game for students to follow. They will do the same work, but earn XP for their character as they do it, adding an element of intrinsic motivation that gets them to engage.
The second important key to this work is getting teachers to understand how much support they stand to gain by inviting technology into their formative assessment planning. Assessing students can be taxing, and becomes more difficult for every extra student in the room. This difficulty is why it is so critical that technology is embraced and welcomed into teacher lives.

For the teachers with 25 or more students in their class, these tools offer a solution to lessen the large workload that comes with grading so many work samples. By using technology in your formative assessments, you allow it to do the “grunt work”, and give yourself more time to effectively plan to meet student needs, needs you can identify with the data already collected for you.

Beyond the benefit of data collection, there is potential for immediate feedback with technology. In the previous example of the spelling assignment, the teacher must collect, and then grade 25 papers. This takes time to do, time they might not have that same day. So the teacher goes home, grades the papers, brings them back the next day, and returns them. The student is then looking at errors from a lesson that they are no longer on, and the full impact of the feedback has been lost. By using technology in our classrooms, we can get students feedback immediately, letting them make connections and corrections about their learning right away.

Maximizing your time as an educator is key to unlocking a next level of instructional prowess. We do not have more hours in the day than anyone else, but it can often feel like we are asked to do so much, that administrators may think we do! What we must do is use every strategy in the proverbial teacher toolbox to make our time as efficient and productive as we can.

REFERENCES


## APPENDIX A

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>ExactPath</td>
<td>Diagnostic assessments that lead to individualized learning paths to promote differentiated learning and student growth. Students participate in online lessons that offer engaging content.</td>
<td><a href="https://www.edmentum.com/products/exact-path">https://www.edmentum.com/products/exact-path</a></td>
</tr>
<tr>
<td>iReady</td>
<td>Motivating online lessons personalized to student academic level. Diagnostic assessment places students at appropriate levels to meet their strengths and weaknesses. Students work through engaging online lessons, and earn currency used to purchase game time in the provided mini-games.</td>
<td><a href="https://www.curriculumassociates.com/programs/i-ready-learning">https://www.curriculumassociates.com/programs/i-ready-learning</a></td>
</tr>
<tr>
<td>Prodigy</td>
<td>Standards aligned math practice in a fun role-playing game environment. Students create an avatar, and assemble a team of “pets” to help them fight monsters in the world. Math problems are solved to defeat enemies, and characters can be leveled up and acquire new spells, gears, and teammates.</td>
<td><a href="https://www.prodigygame.com/main-en/">https://www.prodigygame.com/main-en/</a></td>
</tr>
<tr>
<td>ClassCraft</td>
<td>Game based motivational tool designed to incentivize positive classroom actions. Students create an avatar that they earn cosmetic rewards for, and are able to use powers that give them benefits in the classroom.</td>
<td><a href="https://www.classcraft.com/">https://www.classcraft.com/</a></td>
</tr>
</tbody>
</table>

## APPENDIX B

<table>
<thead>
<tr>
<th>Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>ExactPath Getting Started Resources</td>
<td>A home page built by Edmentum, delivers a central all-you-need area with videos to answer questions about getting started with ExactPath.</td>
<td><a href="https://get.edmentum.com/exact-path-getting-started/">https://get.edmentum.com/exact-path-getting-started/</a></td>
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<tr>
<td>iReady Video Hub</td>
<td>A collection of videos from iReady’s collection that covers all aspects of implementation in the classroom.</td>
<td><a href="https://i-readycentral.com/articles/video-hub/">https://i-readycentral.com/articles/video-hub/</a></td>
</tr>
<tr>
<td>Prodigy Resource Guide</td>
<td>A comprehensive list of all things teachers will need to excel with Prodigy, including getting started, fundamentals, and managing a classroom.</td>
<td><a href="https://prodigygame.zendesk.com/hc/en-us/categories/200110968-For-Teachers/">https://prodigygame.zendesk.com/hc/en-us/categories/200110968-For-Teachers/</a></td>
</tr>
<tr>
<td>ClassCraft Introductory Video</td>
<td>A video to introduce ClassCraft to teachers, administrators, or parents new to the program.</td>
<td><a href="https://youtu.be/M2uqd9ZOMaw">https://youtu.be/M2uqd9ZOMaw</a></td>
</tr>
<tr>
<td>ClassCraft Reference List</td>
<td>An extensive list of all the available resources listed on ClassCraft’s website. Blogs, guides, webinars, and much more can be accessed here.</td>
<td><a href="https://www.classcraft.com/resources/">https://www.classcraft.com/resources/</a></td>
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K–12 ONLINE AND BLENDED LEARNING
Using Makerspaces to Create and Produce Mathematics Manipulatives

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Manipulatives are considered essential tools to scaffold student learning of mathematical topics. Despite the importance of using such tools, the acceptability and affordances of different manipulatives and teachers’ unfamiliarity with them constrain their use. In this chapter, we provide two different maker tools (i.e., 3D printers and Cricut) for teachers to design different mathematical manipulatives. We first discuss the cost-effectiveness and differences of these two maker tools. Then, we address the opportunities makerspace tools provide for pedagogical practices and position teachers as designers and collaborators of their mathematics manipulatives.

**INTRODUCTION**

Students who use manipulatives more frequently have higher mathematics achievement scores (Carbonneau et al., 2013; Uribe-Flórez & Wilkins, 2017), and students who use manipulatives demonstrate more sophisticated mathematical reasoning than students who learn the same content without concrete manipulatives (Donovan & Fyfe, 2022; Rinaldi et al., 2020). Further, manipulatives are effective for mathematics learning from early elementary up through college-level mathematics content (Carbonneau et al., 2013). Although manipulatives are effective tools for teaching and learning mathematics, the mere use of them is not a guarantee for effectiveness (Furman, 2017; Peterson et al., 2014). Moreover, the cost and lack of access to manipulatives is a primary deterrent for their implementation in the classroom (Kosko, 2019; Larkin, 2016).

Makerspaces have gained popularity in the past decade, and involve “communities of practice constructed in a physical place set aside for a group of people to use as a core part of their practice” (Halverson & Sheridan, 2014, p. 502). In recent years, various scholars have begun producing manipulatives with makerspace technology (Akuom et al., 2022; Hoopes, 2018). Yet, much of this work has focused on use of makerspaces to engage teachers in designing manipulatives from scratch rather than on use of makerspaces to gain access to known manipulatives. In this chapter, we share our initial experiences with creating access for teachers to manipulatives with two examples that can be created with smart-cutting machines (i.e., Cricuts) and 3D printers.

**RESEARCH REVIEW**

Effective manipulative use is based on Bruner’s (1966) Concrete-Representation-Abstract (CRA) sequence. In essence, Bruner (1966) suggested that students initially understand a mathematical concept when it can be concretely manipulated (i.e., placing 7 counters in a 10-frame and recognizing 3 are needed to make 10, or $7 + 3 = 10$). As students learn arithmetic, they shift from relying on concrete materials to drawings, before eventually relying solely on numeric
symbols. Students who are exposed only to numerals often don’t understand basic math facts (Baroody et al., 2009). To effectively use manipulatives, and to facilitate the CRA sequence, Laski et al. (2015) suggest that a manipulative is consistently used with a concept over a longer period (i.e., infrequent use isn’t effective), and explicitly describe the relationship between the manipulative and the numeric representation. More than one manipulative can be used if following these recommendations, and this can lead to better recall and understanding of basic facts (Laski et al., 2023).

Although there is ample research on how manipulatives are effective, and on the best ways to use them, many teachers lack access to and training with many basic manipulatives (Kosko, 2019; Larkin, 2016). We suggest that MakerSpace equipment including 3D printers and Cricut (cutting) machines provide a means of significantly reducing the detrimental cost associated with concrete manipulatives with tools. Recent findings suggest that makerspaces encourage teachers to reconsider their perspectives when enacting curriculum (Becker & Jacobson, 2020). In many instances, this is a result of engaging them in the design of materials to be used in teaching. Yet, given that access strongly influences use, we conjecture that teachers and their students will benefit from use of makerspaces to create mathematics manipulatives for normal classroom use.

IMPLICATIONS

We discuss the use of two makerspace technologies: 3D printers and smart cutters. The most common brand of affordable smart cutter is the Cricut, and it is used to cut thinner materials including paper, vinyl, and foam as thick as 2mm. By contrast, 3D printers are typically used to produce PLA plastic shapes of varying sorts. For use of makerspaces to be effective, teachers need to have experience and background knowledge in using the tools and applications, and experience modeling creative and collaborative processes (Corum et al., 2020; Koul et al., 2021). We do not discuss such experiences and knowledge bases here, focusing our chapter instead on the use of such machines.

Affordances of 3D Printers and Cricuts

Earlier, we noted that a significant deterrent to use of manipulatives is access and cost. Makerspace manipulatives significantly reduce such burdens by providing a lower cost for producing manipulatives. For example, fraction tiles typically cost $7–$9 for an individual set, but teachers can produce a plastic set for $1.43 on a 3D printer or $1.76 as foam on a Cricut. Another example are Numicons, a color-coded version of ten frames that cost $30–$40 for an individual set. By contrast, a version of the same manipulative (we call them number frames) can be produced for $4.89 on a 3D printer and $2.25 on a Cricut.

In addition to the cost advantage, Chapman (2021) cites differences between 3D printers and Cricuts that may be useful to consider when purchasing equipment and meeting teachers’ preferences and needs. First, Cricut machines use SVG (scalable vector graphic) files and 3D printers use STL files (stereolithography; a technique for layer-by-layer fabrication). Beyond file format, there is a difference in dimension. The Cricut can cut sophisticated shapes, yet in only two dimensions, while the 3D printer can print objects in layers that offer very specific details. These affordances often come at the expense of the time it takes to produce a figure on a 3D printer. The second difference between machines is the material that can be cut. 3D printers typically require plastic filaments while the Cricut can typically produce various designs on paper, iron-on transfers, card stock, and foam. The list of materials for each device is not exhaustive, and there are special forms of 3D printers and smart cutters that can work with different sorts of materials (concrete from 3D printers, metal from smart laser cutters, etc.). However, the materials and machines discussed here tend to be affordable for schools and teachers. Using the example of number frames and fraction tiles, teachers can find files online at websites like Thingiverse, or our own repository (https://xr.kent.edu/makerspace). 3D printers use STL files and Cricut machines use SVG files.

Example Makerspace Manipulatives

Number frames provide children with a greater sense of number composition and decomposition, while simultaneously providing a visual that relates to prior experiences with ten-frames. You can create this multisensory tool on both Cricut and 3D Printers. After producing the manipulatives, teachers can help students make connections between addi-
tion/subtraction, place value, and basic properties in mathematics. For example, in Figure 1, teachers can use the number frames to demonstrate how first graders can informally use the Associative Property to add 9 and 11 by reordering and reorganizing the number frames that show that $9 + 11$ is $9 + (1+10)$. Children can then be shown how $9 + (1+10)$ is the same as $(9+1) + 10$ or $10 + 10$. Children do not need to count by ones using 10 number frame to show that $9+1$ is 10, since it is already visual similar to a completed ten-frame.

**Figure 1**

*Using 3D printed number frames to demonstrate the associative property*

![Figure 1](image)

Another example involves the use of fraction tiles that can be made with either Cricut or 3D printers. Figure 2 shows fraction tiles as a tool for equivalent fractions, partitioning, and fraction operations. In the illustrated example, a child can model $\frac{3}{4}$ of a whole by finding equivalent parts that fit inside the whole four times and iterating one of these partitions three times. What is so unique about both the Cricut and 3D printer versions of fraction tiles is that a teacher can choose to include or exclude labels. A benefit to labeled tiles is that they can better link the symbolic representation with the concrete. However, there is a limit to their use as a tile labeled $\frac{1}{4}$ will typically serve that explicit role. However, excluding labels can allow for an easier means of showing $\frac{3}{4}$ in multiple ways; thus, illustrating that $\frac{3}{4}$ is a relationship between two quantities (see Figure 2).

**Figure 2**

*Using Cricut created fraction tiles to model $\frac{3}{4}$*

![Figure 2](image)
Creating a Makerspace for Manipulatives

In the previous two examples, we described how the Cricut and 3D printer could produce the same concrete manipulatives. However, in doing so, we did not discuss the primary affordances of producing these manipulatives on each. First, when creating materials with a 3D printer, the process is much longer (several hours) but the product is durable and long lasting. By contrast, manipulatives created with 2-mm foam on the Cricut cost even less than those created on 3D printers and are produced much more quickly (often less than an hour). Yet, they are less durable. Because of these properties, if a teacher has access to both machines, the Cricut can be used for manipulatives that can be taken and used at home by students whereas those produced by the 3D printer can serve as more durable sets in the classroom. For example, concrete manipulatives for conic sections can cost between $20–$30 per set and as a result, most high school students rarely have an opportunity to touch the one display set owned by the teacher. Figure 3 shows a 3D printed version that costs 38 cents made out of plastic and a Cricut cut paper-version made from cardstock (less than one cent). The 3D printed version is durable for use in class, but the Cricut version can allow students to write properties on it, take it home and use it to solve specific problems posed by their teacher.

Figure 3

Side-by-side comparison of conic sections created on a 3D printer and paper-based version from a Cricut (left) as well as an ungeared clock (center) and geared clock (right)

Another distinction between the pragmatic use of Cricuts and 3D printers is that what they can produce can affect the type of manipulative created. For example, the parts for an ungeared clock can be easily cut with a Cricut from paper or other material. However, a 3D printer is more suitable for producing a geared clock (see Figure 3). The affordances of each machine should inform what machines and materials teachers and schools invest. To aid in this process, we provide a list of resources and materials in Appendix A.

Beyond their immediate use by teachers as a source for less expensive classroom materials, makerspace manipulatives provide a potential opportunity for informal professional development. Teachers can modify both SVG and STL files on free editors like TinkerCad to accommodate personal teaching preferences (i.e., including or excluding labels on the manipulative). If a modification isn’t effective, a teacher can more easily create a slightly different version of the same manipulative without the stress associated with paying for high cost commercial manipulatives. Additionally, making math manipulatives with makerspaces is often collaborative in nature, and provides teachers with opportunities to visualize mathematics in new ways (Halverson & Sheridan, 2014). Teachers can work together on collaborative projects (Calabrese et al., 2018), and if supported by maker mentors they learn new technologies and troubleshoot their designs while engaging with other makers online through maker forums, social media, or YouTube videos (Calabrese et al., 2018; Martin, 2015).
Acknowledgements

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References


APPENDIX A

Links to Materials and Devices:

Cricut & Smart Cutters:

*Cricut Maker 3* and *Cricut Explore 3* models each allow for cutting 2mm thick foam, card stock paper, and other material (although the two prior materials are most useful for manipulatives). You will want to purchase the following supplemental material for cutting foam:

- Deep Blade and Housing kit ([available on Amazon](https://www.amazon.com)), as well as replacement blades when your blade *eventually* wears down.
- Cutting mats compatible with your Cricut device ([available on Amazon](https://www.amazon.com)).
- 2mm thick foam. This typically comes in sheets and you will want to have a variety of colors for what you create ([available on Amazon](https://www.amazon.com)).

Brother also makes a smart cutter device (ScanNCut DX) at a similar price point as Cricut. The device has its own unique set of blades and mats, and though it will cut the same sheets of foam, there is a smaller community that uses this particular device.

3D Printing:

There are hundreds of 3D printers available at a wide range of price points. We recommend the Prusa Mini ([available here](https://www.prusasoft.com)) as an entry-level device due to the excellent customer service from Prusa, numerous tutorials and resources to learn and grow (Prusa provides these for free), and because the device simply works as advertised (we have had poor luck with some manufacturers). There are less expensive 3D printers, but they require more work on the part of the user. Here are a few popular alternatives:

- SUNLU T3 ([Available on Amazon](https://www.amazon.com))
- Creality Ender 3 ([Available on Amazon](https://www.amazon.com))
- Voxelab Aquila X2 ([Available on Amazon](https://www.amazon.com))

We will note that the Prusa Mini and SUNLU T3 both have removable print plates and auto-leveling (both of these reduce the work of the user).

One important thing to purchase with a 3D printer is PLA filament. This plastic comes in spools (typically 1Kg in weight). We have found IIID Max ([https://iiidmax.com](https://iiidmax.com)) and SUNLU ([https://www.sunlu.com/](https://www.sunlu.com/)) to each provide reasonable prices and good quality filament. To be clear, there are “better quality” filaments but these are typically used for industrial applications and not classrooms.

There are other materials essential to make your 3D printer and printing function well:

- **0.6mm nozzle** to increase your print speeds (E3D V6 is a good quality nozzle that costs about $10 – [available on Amazon](https://www.amazon.com)).
- You will want a simple metal **paint scraper** to help remove prints from the print bed ([available on Amazon](https://www.amazon.com)).
- A **flush cutter** will help cut any loose bits of plastic off of your 3D prints and is a needed tool ([available on Amazon](https://www.amazon.com)).
- Cotton balls and 75% Alcohol can be used to clean the print bed (surface where 3D prints are made). This should be done periodically or if you have touched the surface (oil from hands can keep prints from sticking). Once every several dozen prints, 100% Acetone can be used if needing a “deep clean” of the print bed.
Links to SVG (Cricut) and STL (3D Printer) Files and Repositories:

Makerspace Manipulatives:  [https://xr.kent.edu/makerspace/](https://xr.kent.edu/makerspace/)
- Our own (growing) repository for manipulatives that can be produced with Cricuts and 3D printers. The website also includes resources for how to use the manipulatives.

SVG’s From Anna:  [https://www.svgsf romana.com/](https://www.svgsf romana.com/)
- Among other things, there are inexpensive files for fraction strips, ten frames, etc.

Thingiverse:  [https://www.thingiverse.com/](https://www.thingiverse.com/)
- Online, searchable database for STL and SVG files.

TinkerCad:  [https://www.tinkercad.com/](https://www.tinkercad.com/)
- A free editor. You can upload existing STL and SVG files to “tweak” them or create your own from scratch.

Links to Tutorials on Using Cricut and 3D Printers:

For 3D Printing:

We recommend the Prusa brand (particularly the Prusa Mini for first time 3D printing) because it works out of the box, and if anything happens to go wrong, their customer service responds quickly and solves the issue. Here are tutorials and guides from Prusa and others:

Overview:  [https://youtu.be/i0DaM4_4ajo](https://youtu.be/i0DaM4_4ajo)
Assembly:  [https://youtu.be/vA95VvdquA](https://youtu.be/vA95VvdquA)
Changing the Nozzle:  [https://youtu.be/txt6xV6X88](https://youtu.be/txt6xV6X88)
- This is helpful if you want to change from a 0.4mm to 0.6mm (more filament comes out of the nozzle → faster printing → slightly less detailed).

For Cricut:

Comprehensive Overview:

Teaching for Creativity with 3D Printing and Design Thinking

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Educators often ask students to be creative in classroom activities, yet the concept of creativity can be vague and ill-structured for many teachers. Because of this lack of definition, teachers may not feel comfortable with strategies to increase creativity in their daily lessons. One technology that has been shown to improve creativity is 3D printing, especially in conjunction with design thinking. This chapter provides an overview of the research on 3D printing, creativity, and design thinking. Additionally, research-based, practical advice is offered for integrating 3D printing and design thinking with creativity in mind. Finally, training materials, including sample curriculum and a lesson plan template, are provided to give teachers a roadmap for how to plan and teach for more creativity in their classrooms.

INTRODUCTION

In education, teachers often tell students to “be creative” during their daily work in the hope that this phrase ignites uniqueness, novelty, or originality in them. However, a teacher’s educational allowance to “be creative” enables them to do so much more. For example, creativity fosters confidence, improves students’ critical thinking, increases productivity, and enhances motivation.

However, despite the many benefits of creativity, educators are not consistently integrating this into their daily lessons, particularly in conjunction with technology tools. This limited integration of creativity is understandable given the multitude of definitions surrounding the concept. Further, the idea of creativity has traditionally been seen as a fixed, general skill instead of a subject-specific skill that can be improved with practice, as recent research suggests.

One emerging technology for adding creativity to instruction is 3D printing, especially in conjunction with the instructional strategy of design thinking (Greenhalgh, 2016). However, recent research (Novak et al., 2021) has shown that applications of 3D printing in the classroom can sometimes fall short in the area of creative teaching and learning, with many 3D printed products being novelties (e.g., bookmarks, symbolic representations) or replicas (e.g., historical artifacts, nucleus of a cell). Practical steps are needed for teachers on how to effectively integrate design thinking and 3D printing to effectively cultivate creative capacity in students.

RESEARCH REVIEW

There are several important research findings related to creativity and 3D printing in education. For example, when users build 3D digital models, they are using abductive reasoning, a necessity for creativity, by thinking through solutions to problems, testing those solutions, and then modifying their designs based on data from testing (Iversen et al., 2016). Trust and Maloy (2017) established that creativity was one of the main skills developed during 3D printing, with other research also noting that design thinking can act as a mediator between 3D printing and creativity (Verner & Merksamer, 2015). Creativity and 3D printing both tend to include aspects of problem solving, independent learning, critical thinking, and perseverance (Trust & Maloy, 2017). Regarding subject areas, 3D printing has been used for creative problem solving in a variety of educational settings, mostly in engineering, science, and mathematics (Ford & Minshall, 2019). Finally, one study observed that there was a limited availability of high-quality educational materials on the topic of 3D printing, specifically noting that curricula and lesson planning resources were needed for teachers (Ford & Minshall, 2019). Additional research has also noted that technical skills were important to a teacher’s ability to use 3D printing for purposeful instruction (Leinonen et al., 2020).
One specific study related to the relationship between 3D printing, creativity, and design thinking (Brannon, 2022) can offer practical advice and resources for educators. To elaborate, in this study design thinking was used as an intervention to help understand whether or not design thinking as an instructional strategy had an impact on creativity in a 3D printing unit. The study designed and tested teacher education training materials on the topics of 3D printing and design thinking. A curriculum of 3D printing and design thinking were developed in addition to a 3D printing/design thinking lesson plan template for teacher use.

Overall, the study found that design thinking and 3D printing could empower teachers to think more creatively (creative process) and produce more creative lesson plans (creative product) for their students. Another finding of the study was that a teacher’s beliefs and attitudes toward creativity (creative person) and their overall environment (creative press) may not be impacted by the integration of design thinking with 3D printing. Positive results regarding the creative thinking process and creative lesson planning in this study may suggest that the use of design thinking along with 3D printing is a practical method for improving creativity in classrooms.

**IMPLICATIONS**

The results of Brannon (2022) led to several implications for education in regard to creativity, 3D printing, and design thinking. To put these results into practice, there are two main perspectives to consider: the teachers and the students.

**Preparing Teachers**

**Understanding Creativity**

When the purpose for using 3D printing and design thinking is to improve creativity in the classroom, it is important to first understand the concept of creativity. Creativity remains elusive in the K–12 education environment because it is ill-defined and unstructured. From the many existing definitions of creativity, Brannon (2022) focused on a singular definition which described creativity as “the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context” (Plucker et al., 2004, p. 90). This definition tells us that creativity is multi-dimensional and is an interaction between four different components of creativity. Rhodes (1961) described these four components of creativity as creative press (the environment that influences how creative a student can be), creative process (the procedural thinking which leads to creative thought), creative person (the individual person’s beliefs and abilities related to creativity), and creative product (the final creation produced from creative thoughts). These multiple components demonstrate the need to be thoughtful in teaching for creativity since there are many different educational considerations. In addition to the four components of creativity, it is also important to understand that creativity is not a general skill that students either possess or not. Instead, creativity has been shown to be a subject-specific skill. This means that a student could be deemed creative in a specific subject area, like mathematics. This perspective becomes more important when we look at general teacher usage of 3D printing, since students could be using a 3D printer across many different disciplines.

In order to work toward the end goal of teaching creatively, educators need to take part in professional development to better understand what creativity is, how it is recognized in the classroom, why creativity in education is important, and how creativity can be measured. Appendix A lists some recommended books on creativity in education that can give teachers both the background knowledge and the skills to enact creative teaching. One strategy cited often for improving creativity in educational experiences is the use of design thinking, which will be further detailed in this chapter.

**Understanding 3D Printing**

Teachers also need to have a well-rounded understanding of the technologies they integrate into their classrooms, such as 3D printing. Three-dimensional, or 3D, printing is a process by which a machine creates a physical model of a digital image by adding melted material, usually ABS plastic, layer by layer. The digital images for use with a 3D printer are created in computer-aided design (CAD) programs such as Tinkercad, which is an easy-to-use, free online program.
for creating 3D models. Tutorials for programs like Tinkercad are helpful for teachers that are new to 3D printing. Tutorials become helpful because it is important to find a comfort level with the 3D modeling technology before you first integrate it into your classroom with students (Joo et al., 2018). A general tutorial for creating a boat in Tinkercad can be found in Appendix B.

In addition to improving creativity, teachers need to know the general benefits and drawbacks of using 3D printing in the classroom (Ford & Minshall, 2019). For example, in addition to improving creativity, 3D printing can build 21st Century skills (Trust & Maloy, 2017), empower student-driven learning (Schelly et al., 2015), improve student’s motivation and interests (Kwon, 2017), and increase students’ mathematical skills (Bull et al., 2014). Teachers also need to understand how to use 3D printing in the classroom, including viewing examples of 3D printed products. As with any technology, problems may arise from time to time. Because of this, another important skill for teachers is troubleshooting 3D printers. Understanding how to fix any possible device problems may enable a smoother learning experience for students, and they will greatly detract from a teacher’s stress during the 3D printing lesson.

Understanding Design Thinking

Finally, to ensure that design thinking has the intended effect of improving creativity in the classroom, it needs to be implemented effectively and with fidelity. Design thinking is a process of purposefully thinking about problems and the context in which they exist, starting by gaining an empathetic understanding of the problem and ending with the implementation of a solution to the problem (Diefenthaler et al., 2017). Design thinking includes the use of a design thinking problem, which is an authentic, real-world problem that students try to solve using the procedural thinking of the design process. To activate creativity, the design problem should be open-ended with various possible solutions. An example of a design thinking problem for elementary science, along with correlating NGSS standards and objectives, is found in Appendix C.

When using design thinking, a specific process is typically selected and followed to guide the creative problem-solving process. One excellent design thinking model for educational use is the LAUNCH Cycle, which utilizes a spiral design process, which aims at refining ideas over time and emphasizing learning from mistakes (Spencer & Juliani, 2016). The initial step of the LAUNCH Cycle, Look, listen and learn, encourages students to find problems. After finding the problem, students seek to determine the root cause of the problem (Ask lots of questions and Understand the problem or process). Next, students select ideas which might seek to solve the problem (Navigate Ideas) and create a product that aligns with those ideas (Create). Once the product is created, students test the product to see if it results in their desired solution. Students use the results from their tests to learn and refine their product in order to improve their results (Highlight and Fix). Once students have iterated and refined their product enough, they present a final version to an authentic audience (LAUNCH).

Preparing Students

In addition to teachers’ professional development on the topic, students must also be prepared to learn about 3D printing and design thinking. One way to approach this is to view 3D printing or design thinking as any other skill that students learn, which both need to be explicitly taught with sufficient scaffolding, including plenty of teacher modeling and student practice (Koh et al., 2015). However, there are specific considerations which can make the learning of these skills/methods easier over time. Below are some practical tips for successful integration of 3D printing and design thinking in the classroom followed by an overview of lesson planning.

- **Work for fun first:** Allow students to create fun 3D modeled and printed items when they first have access to the technology. Encouraging open-ended production can improve creative mindsets toward the technology while also increasing their confidence in ease of use with a new technology (Malureanu et al., 2021).
- **Choose a best-fit design model:** There are many design thinking models in existence. Select a model that fits your teaching style, time allowance, and instructional needs.
- **Take it slow:** The process of design thinking should be purposefully planned into the day’s activities, leaving plenty of time for students to think and work with each step of the process. Plus, 3D modeling can take time for students to finalize their creations. Time constraints can decrease creative problem solving (Acar et al., 2019).
• **Embody a growth mindset**: Students pick up on every move we make, including our habits! Cultivate a classroom culture of learning from mistakes and perseverance over failure so that students are more likely to keep trying when they fail or struggle.

• **Include children’s literature**: Read students books about problem solving to engage them in mindsets of perseverance (see Appendix D for a list of children’s literature to use in conjunction with design thinking).

• **Present findings**: Include a final presentation for students to share both their work and their thinking processes regarding how the 3D object can solve the design problem.

**Lesson Planning**

Putting all of the experiences with 3D printing and design thinking together can be daunting. To aid in this task, a 3D Printing and Design Thinking lesson template has been provided in Appendix E. This template ensures that the 3D printing lesson begins with academic content standards in order to effectively integrate 3D printing for learning. Additionally, the use of a lesson plan template, such as the one in this chapter, results in a pre-planned 3D printing routine, which is recommended in research (Novak & Wisdom, 2020). The lesson should be student-centered and ensure that there is a metric for assessment, preferably a rubric.

**REFERENCES**


Spencer, J., & Juliani, A. J. (2016). We need creative classrooms (chapter one of launch: Using design thinking to boost creativity and bring out the maker in every student).


APPENDIX A

List of Resources

1. List of Professional Books on Creativity in Education

   ● *Creating Innovators: The Making of Young People Who Will Change the World* by Tony Wagner
   ● *Creative Schools: The Grassroots Revolution That’s Transforming Education* by Sir Ken Robinson and Lou Aronica
   ● *Creativity: The Psychology of Discovery and Invention* by Mihaly Csikszentmihalyi
   ● *Creativity and Innovation: Theory, Research, and Practice (2nd Edition)* by Jonathan A. Plucker
   ● *Developing Creativity in the Classroom: Learning and Innovation for 21st-Century Schools* by Todd Kettler, Kristen N. Lamb and Dianna R. Mullet
   ● *Intention: Critical Creativity in the Classroom* by Amy Burvall and Dan Ryder
   ● *Invent To Learn: Making, Tinkering, and Engineering in the Classroom* by Sylvia Libow Martinez and Gary S. Stager
   ● *Nurturing Creativity: An Essential Mindset for Young Children’s Learning* by Rebecca Isbell and Sonia Akiko Yoshizawa
   ● *The Cambridge Handbook of Creativity (2nd Edition)* by James C. Kaufman and J. Sternberg
   ● *The Creative Classroom: Innovative Teaching for 21st-Century Learners* by Keith Sawyer

2. Tinkercad Boat Tutorial

   Click here to access a step-by-step tutorial for creating a boat in Tinkercad. Additional videos and resources are available on this document as well.

3. NGSS Standards-Based Design Problem

   Below is a sample design problem that has been correlated to one of the Next Generation Science Standards (NGSS).

   **Grade Level:** 5th

   **NGSS:**

   ● 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
   ● 3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
   ● 3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

   **Standards-Based Learning Objectives:**

   ● At the end of this unit, students will be able to describe how sound travels through matter by demonstrating how sound interacts with their 3D object.
• At the end of this unit, students will be able to describe how sound waves and the transfer of sound as energy impacts the measurement of sound (in decibels).
• Throughout the learning unit, students will demonstrate knowledge of the design process by applying the steps of the LAUNCH process correctly to the creation of their 3D object.

Sample Design Problem:

• Because of Covid-19, the principal needs to hold the grading period awards assembly for students outside of the school building. During their assigned time period, each class will come outside and sit in a socially distanced layout for their own awards assembly. To help improve the mood and morale (encouraging students), the principal wants to play some music for the students who are receiving their awards using his cell phone. However, there is no electricity available at the assembly location. Can you design something with the 3D printer that will help the principal’s cell phone speaker to be heard loudly outside without using any electrical power?

4. List of Children’s Literature

Below are some children’s literature books to utilize with design thinking instruction (or any creative problem-solving activity):

• Beautiful Oops! by Barney Saltzberg
• Ish by Peter Reynolds
• The Dot by Peter Reynolds
• The Girl Who Never Made Mistakes: A Growth Mindset Book for Kids to Promote Self Esteem by Mark Pett and Gary Rubinstein
• The Shape of Ideas: An Illustrated Exploration of Creativity by Grant Snider
• The Thing Lou Couldn’t Do by Ashley Spires
• What Do You Do with a Problem? by Kobi Yamada
• What Do You Do with an Idea? by Kobi Yamada

5. 3D Printing and Design Thinking Lesson Template

<table>
<thead>
<tr>
<th>Title of Lesson</th>
<th>Give your lesson a title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson Summary</td>
<td>Briefly describe what students will learn and what 3D model they will do in this lesson in a 5-6 sentence paragraph.</td>
</tr>
<tr>
<td>Estimated Overall Time</td>
<td>How long do you estimate this entire lesson will take? Hint: Complete this after the lesson procedure and find the overall time by adding up all of the times in that procedure. It is important not to rush either the 3D printing or design thinking processes.</td>
</tr>
<tr>
<td>Grade Level and Subject</td>
<td>Identify the content area and grade-level for whom the lesson is written.</td>
</tr>
<tr>
<td>Statement of Content Standards</td>
<td>Include the applicable learning standards that will be addressed in the lesson.</td>
</tr>
<tr>
<td>Learning Objectives Make sure to use the SMART format</td>
<td>List what you want students to know and to be able to do by the conclusion of the lesson. Objectives should be Specific, Measurable, Attainable, Relevant, and Time-based.</td>
</tr>
</tbody>
</table>
**Lesson Procedure**  
List the steps or progressions in a logical sequence of how you will teach the lesson with what activities. The procedure should be detailed and one that could easily be used for students of the intended grade level. Make sure to follow the LAUNCH cycle steps, integrating them carefully into the lesson. To do this, you will need to formulate a design challenge and decide how you would go about scaffolding learning so that students can successfully complete the challenge. After completing the lesson procedure, fill in the table below to describe how each of the LAUNCH Cycle steps are used within the lesson procedure.

**Launch Steps:**
1. Look, listen, and learn
2. Ask tons of questions
3. Understand the problem or process
4. Navigate ideas
5. Create a prototype
6. Highlight and fix
7. LAUNCH

**Learning Environment**
Describe the general learning environment, including both the physical space (e.g., light, temperature, locations of furniture) as well as the social-emotional environment (e.g., What is the general atmosphere? How will you develop positive relationships with students?) that you will create during this lesson as the teacher. Think about where the 3D printer is located when considering the physical space. Consider the classroom culture you would like to create, including mindsets, when considering the culture and climate of the classroom.

**Assessment**
Explain how you will determine that the students have learned what you intended to teach them. Use a rubric if possible. Keep the rubric general when possible to encourage creativity.
Getting Teachers Truly Prepared for PreK–12 Online and Blended Instruction

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The COVID-19 pandemic forced schools to move to online and blended learning. The abrupt change was a challenge for many teachers, particularly those that lacked professional development and experience in these modes and environments. The COVID-19 pandemic is beginning to end, but there are probable future circumstances where teachers and students will need to temporarily move to online or blended learning to maintain continuity of instruction. Even without natural disasters or global diseases, there are educational benefits for schools to incorporate both blended and online instruction. In this chapter, the authors provide teachers with recommendations for how to capitalize on lessons learned from preK–12 online learning research to increase the chances of their success and their students’ success with online and blended learning. The recommendations include being aware of research-based frameworks, being aware of existing metrics and instruments, having experiences as online learners, and providing students with opportunities to learn in blended and online environments.

INTRODUCTION

PreK–12 online and blended instruction has existed for almost 30 years (Ferdig & Kennedy, 2014; Kennedy & Ferdig, 2018). However, the concept of online learning—as well as its practical implementation—became personal for elementary and secondary administrators, teachers, staff, and students during the COVID-19 pandemic.

This was not the first time endemics, pandemics, or natural disasters caused schools to close. For instance, both SARS and H1N1 forced many school closures in Asia or in countries with high levels of migration to and from Asia (Barbour, 2010). School responses varied with some schools simply closing and failing to provide alternatives to students, while others began to use online learning to offer educational continuity (e.g., Alpert, 2011; Barbour et al., 2011; Borja, 2003; Latchem & Jung, 2009).

Unfortunately, even with these early examples and warnings, educational systems around the world were woefully and inadequately prepared for COVID-19. Ignoring much of the research that existed, academics had to use terms like emergency remote instruction to describe the teaching and learning that was taking place (Barbour et al., 2020; Hodges et al., 2020). As the pandemic wanes, schools and teachers have returned to a new normal (e.g., An et al., 2021), yet still ignoring past experiences and the need to be prepared for what may come in the future. The purpose of this chapter is to address this problem, providing suggestions for teachers to capitalize on lessons learned from preK–12 online learning research.
RESEARCH REVIEW

There are two key areas of research for teachers to understand in addressing the move to online and blended instruction. The first relates to historical research on K–12 online and blended instruction (e.g., Kennedy & Ferdig, 2018). In short, research has provided evidence that K–12 online and blended instruction can be as effective (and, in some cases, more effective) than traditional face-to-face education (Cavanaugh et al., 2004; Cavanaugh et al., 2009). That does not mean it will be. As with all technologies, there are affordances and constraints of online and blended learning that require careful consideration during implementation (Ferdig, 2006). That is the reason why, in part, so many schools failed during pandemic online education (Barbour, 2022). K–12 online and blended learning has promise, but it requires teacher preparation and professional development.

The second area of research relates to the calls for educational reform post-COVID (Baumgartner et al., 2022; Ferdig et al., 2020; Ferdig & Pytash, 2021; Hartshorne et al., 2020; Mouza et al. 2020). Most notably, in Hodges et al. (2022) we outlined six concrete actions that were required of all teacher education programs by the year 2025. These recommendations included a call for these programs to be required to focus on K–12 online and blended learning by incorporating specific coursework that was delivered in online and blended mediums and providing opportunities to undertake field experience in online and blended settings. Additionally, faculty in these programs needed to develop validated, research-based frameworks and standards, as well as metrics and instruments to assess those frameworks and standards.

However, even if teacher education programs were able to achieve all six of these suggestions today, it does not address the gap in preparation for the millions of teachers currently in classrooms in the United States or the tens of millions of teachers worldwide. Even if the closures are not due to future pandemics, it is well documented that schools regularly close on a short-term basis due to natural cycles of inclement weather (Barbour, 2022; Ferdig, 2018). Additionally, longer term school closures are often required following natural disasters (Baytiyeh, 2018; Dabner et al., 2012; Mackey et al., 2012; Rush et al., 2016; Zaka, 2013). Even individual students often miss school due to individual health issues (Black et al., 2022). The potential educational impact of each of these situations could be moderated if preK–12 school systems and individual teachers were better prepared to pivot their instruction to distance delivery.

IMPLICATIONS

While the goals and objectives we presented in Hodges et al. (2022) were aimed at teacher education programs, many of the recommendations can serve as a guide for teachers preparing for the future. The remainder of this chapter breaks down these recommendations and next steps for teachers.

Teachers Should Be Aware of Research-Based Frameworks

At present, there is one research-based framework related to K–12 online learning that teachers should be familiar with. At its most basic level, the Academic Communities of Engagement (ACE) framework (Borup et al., 2020) indicates that students will have success in an independent learning environment when they are fully engaged affectively (i.e., emotional), behaviorally (i.e., actions), and cognitively (i.e., learning).

Figure 1 represents the relationship between affective, behavioral, and cognitive engagement (Borup et al., 2020). The inner black triangle represents a student’s ability to engage based on their own knowledge, skills, and aptitude. The support ability from the student’s personal community is represented in dark blue, while the support represented by the larger course community is represented in lighter blue. Each student comes to the learning experience with their own inherent knowledge, skills, and aptitudes. Each student also comes to the learning experience with specific support from their family and friends (i.e., personal community). It becomes the responsibility of the teacher, school, and district (i.e., the course community) to provide the support that is missing to ensure that the student has success. Borup et al. (2020) suggested that the “goal of the support communities is to help the student increase engagement to the level of engagement necessary for academic success, as represented by the dotted line” (p. 810).
For example, teachers might have a student who could independently achieve high levels of affective engagement but had relatively low levels of behavioral and cognitive engagement. That same student’s own personal community might only be able to provide a small amount of support towards their affective, behavioral, and cognitive engagement. In this example, the teacher would need to ensure a high degree of support through the course community in all three dimensions in order for the student to be able to have success (see Figure 2).
As teachers do not know what levels of affective, behavioral, and cognitive engagement their students will have, or the amount of support that the student can count on from their personal community, they need to plan a full range of course community supports. While this support could be provided on a student-by-student basis, it is far less work for the teacher to make sure that there is a full range of course community support opportunities as a part of their initial plan-
ning. This support is then readily available to be used by any student, regardless of the shape of their own individual and personal community triangles.

Teachers Should Have Students Take an Online Readiness Instrument

While there are a few validated instruments within the field of K–12 online and blended learning, one of the more useful is the Educational Success Prediction Instrument (ESPRI). The ESPRI (Roblyer & Marshall, 2002) was designed to predict whether students would have success in an independent learning environment (i.e., online learning). Roblyer and her colleagues were able to demonstrate that the instrument was able to reliably predict whether a student would successfully complete an online course between 80% and 100% of the time (Roblyer et al., 2006; Roblyer & Davis, 2008; Smith et al., 2005). The current instrument has twenty-five questions around these four areas:

1. technology use/self-efficacy (self-assessment of one’s ability with technology),
2. achievement beliefs (confidence in one’s ability to learn, an aspect of locus of control),
3. instructional risk-taking (willingness to try new things and risk failure in instructional situations, related to locus of control),
4. and organization strategies (ways to organize for more efficient learning). (Roblyer et al., 2008, p. 102)

While the stated purpose of the instrument is to predict student success in online learning, it is more useful to classroom teachers as a way to determine their students’ readiness for online learning and the types of support that they may need to have success in that environment. At a most basic level, teachers could have their students complete the ESPRI and then simply average the students’ scores on the seven point scale for each of the four areas to build a profile for their students (see Appendix A for a copy of the instrument).

For example, Siko (2014) was a high school chemistry teacher teaching two blocks of IB chemistry with a less experienced colleague during the school’s first block of the day. These two teachers decided to offer the course in a blended format. Students had the ability to complete much of the static content through online learning; the only mandatory classes were “examinations, labs, and review days, as well as on specific days when the instructor felt that a live lecture would be prudent” (p. 6). The teachers used the students’ results on the ESPRI to help determine which students were able to complete the online learning from home and which ones would be required to come to school to complete the online content.

Teachers Should Have Experiences as Online Learners

When one of the first virtual schools in the United States was created, it set for itself seven major goals (Pape et al., 2005). One said that before any teacher could design or teach one of their online courses, that teacher had to first complete an online professional development course themselves (Zucker & Kozma, 2003). The basic concept beyond this goal was that in order to effectively provide online instruction, a novice teacher needed to experience and gain “exposure to appropriate educational strategies and technologies” used in that environment (Kozma et al., 1998, p. 2).

This model of having the teacher complete some form of online course before they began teaching online is one that is now used by most K–12 online learning programs. It is also a great place for a practicing teacher to begin their experience with K–12 online and blended learning. There were already many online learning opportunities for teachers prior to the pandemic. However, with the sudden transition to remote teaching in 2020, there is a plethora of new online professional development and in-service teacher education opportunities. The examples provided in Appendix B are largely focused on teaching in an online and/or blended environment.

The examples in Appendix B notwithstanding, there are literally countless opportunities to engage in online professional learning related to almost any topic (see Coursera, PBS, and edX). Most discipline-based professional associations have their own catalog of offerings (e.g., statewide and national bodies focused on mathematics, science, English language arts, social studies, and other subject areas), as well as opportunities provided by numerous education-focused non-profit organizations. For example, Wellness for Educators offers a variety of synchronous and asynchronous professional learning opportunities focused on practices and strategies that teachers can use to focus on their own physical, so-
cial, mental, and emotional wellbeing (something we would suggest would be useful to any educator). Regardless of the focus of the professional learning, having the experience of being an online learner provides teachers with a sense of empathy for the struggles that their own students might face if and when they begin to experiment with online and blended learning in their own teaching (Bouton, 2016; Davis & Rose, 2007; Meyers et al., 2019).

**Teachers Should Provide Online and Blended Experiences for Their Students**

Each student comes to a learning experience with their own skills, knowledge, and attitudes from prior experiences. As the world was faced with the pandemic pivot to virtual education, those prior experiences for most students did not include online learning. Students might have had some exposure to blended learning, but it was likely not a significant percentage. A lack of experience with online and blended learning could negatively impact students’ success with these learning experiences. Stated positively, gaining experience with online and blended instruction could provide several positive outcomes for students.

Rather than wait for an emergency need, teachers should provide online and blended experiences for their students when there is a less critical or stressful need to do so. Allowing students to have lower-stakes work in these environments will help them be prepared to be successful in online or blended settings when needed. For instance, it will help prepare preK–12 students for college (Lee, 2021) and work experiences (Mouratidis & Papagiannakis, 2021). It also can improve their self-efficacy. Self-efficacy is the belief that an individual has in their ability to perform specific behaviors that lead to achieving certain goals, and it is an indication of their confidence in exerting control over their motivation, behavior, and social environment (Bandura, 1977; 1986; 1997). Self-efficacy beliefs are thought to be developed through four primary sources: mastery experiences, vicarious experiences, social persuasion, and physiological and affective state (Bandura, 1977). Providing students experiences designed to promote their success as online and blended learners can allow students to build positive self-efficacy beliefs toward online and blended learning through at least three of the four traditional sources of self-efficacy development: mastery experiences (succeeding as an online and blended learner), social persuasion (teacher feedback or praise about student success), and physiological and affective state (low stress exposure designed for student success).

Entire books have been written about ways to introduce online and blended instruction into preK–12 environments. However, a great place for teachers to start is to consider the seven pillars of instructional practice that support student learning in online environments (Johnson et al., 2022). The pillars include:

1. Evidence-based course organization and design
2. Connected learners
3. Accessibility
4. Supportive learning environment
5. Individualization
6. Active learning
7. Real-time assessment

Each of these pillars could be expanded into full-length chapters, and thus, teachers are encouraged to consult additional resources and support for implementing them. In general, the goal for organizing a course should be “creating environments that are navigable, visually streamlined, and clearly organized” (Johnson, et al, 2022, p. 18). For connecting learners, online learning be designed so that learners develop a sense of connection, “both to others in the learning community and to course content” (p. 21). In the area of accessibility, attention to universal design for learning (UDL) is recommended. The aforementioned ACE framework (Borup et al., 2020) can be used for supportive learning environments, particularly with “parents being explicitly invited to participate in children’s learning” (p. 25). Individualization can be addressed by using the affordances of technology to customize learning options for students’ needs (i.e., pacing, content focus, or peer collaboration). Problem-, project-, and inquiry-based learning are techniques recommended for implementing active learning. Finally, for assessment, it is recommended that teachers incorporate formative assessments as well as summative assessments, and that students be provided with options to demonstrate their learning.

In many blended learning models, students learn in a variety of arrangements involving the use of technology for some elements, and no technology for others. They may spend some time in face-to-face classes with a teacher, some-
time collaborating with peers in small groups, and some time working independently. Blended learning often benefits from a flexible learning space that is designed to support different types of learning, with technology and without technology. For example, there may be physical areas for collaboration, informal learning, and individual study, some using technology. Advice for designing the digital elements of online learning discussed above should be incorporated into the digital and online elements of blended learning.

REFERENCES


Ferdig, R. E., & Kennedy, K. (2014). *Handbook of research on K–12 online and blended learning*. Carnegie Mellon University, Educational Technology Center Press. [https://press.etc.cmu.edu/file/download/470/e0e962c-d533-4314-a8f1-7ce4018531f](https://press.etc.cmu.edu/file/download/470/e0e962c-d533-4314-a8f1-7ce4018531f)


**APPENDIX A**

**Education Success Prediction Instrument**

This survey is designed for high school students who are interested in online and/or blended learning courses. Please answer the following questions as accurately as you can.

**DIRECTIONS:** Put an “X” in the box corresponding to the number indicating how much you agree or disagree that the statement describes you. A “1” is “Strongly Agree” and a “7” is “Strongly Disagree”.

**Technology Use/Self-Efficacy**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I know how to locate a document or a program on my computer.</td>
<td></td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>2. I know how to use a browser to locate Internet sites.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I feel comfortable using a computer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I know how to use an Internet search engine to locate information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I have easy access to a computer with Internet capability.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I have a computer in my home.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I know how to send an attachment in an e-mail.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I use e-mail or instant messaging at least once a week.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I have good word processing skills.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. When I have to do something new on a computer, I usually try to figure it out myself.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Achievement Beliefs**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Many times, I lose interest in attaining the goals I set.</td>
<td></td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>12. I rarely set goals for myself.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I believe I am a high achiever.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I find that I try harder if I set high goals for myself.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I study hard for all of my classes because I enjoy acquiring new knowledge.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. I tend to persist at tasks until they are accomplished.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Risk-Taking Beliefs

<table>
<thead>
<tr>
<th>Belief</th>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>17. I do not care what other people think of me if I make mistakes.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I am not afraid of making mistakes if I am learning to do new things.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. I like taking chances and performing risky tasks in learning situations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. If I am given a task to perform that I know little about, I don't mind taking a chance.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. When I am learning something new, it is okay if I make errors.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. I am afraid of failure if I take risks.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Organization Beliefs

<table>
<thead>
<tr>
<th>Belief</th>
<th>Strongly Agree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>23. I find it easier to study for an important test by breaking it into subparts rather than studying the whole subject matter at one time.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. I keep my notes on each subject together arranged in a logical order.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. I will often set short-term goals to help me reach a long-term goal.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B

Sample List of Educational Opportunities to Take Online Learning Experiences

Numerous organizations provide synchronous webinars:

- Aurora Institute - https://aurora-institute.org/events-webinars/
- Digital Learning Collaborative - https://www.digitallearningcollab.com/webinars
- Global Online Teacher Education Center - https://gotec.cehd.gmu.edu/ OR https://www.youtube.com/@masongotec
- International Society for Teacher Education - https://www.iste.org/professional-development/iste-u/microcourses
- Texas Digital Learning Association - https://www.txdla.org/webinars/

Many K–12 online learning programs and vendors offer their own professional learning opportunities in the form of both facilitated and self-paced online courses:

- Desire2Learn (D2L) - https://www.d2l.com/solutions/k-12/teaching-and-learning-webinars/
- Florida Virtual School - https://www.flvs.net/community/courses-for-educators
- Georgia Virtual School - https://gavirtualpd.catalog.instructure.com/
- Michigan Virtual School - https://michiganvirtual.org/professionals/

Some universities offer certificate and endorsement programs in online teaching and learning:

- Arizona State University’s Certificate in Online Teaching for Grades K–12 - https://degrees.apps.asu.edu/masters-phd/major/ASU00/TEEDTGRCT/online-teaching-for-grades-k-12-graduate-certificate
- George Mason University’s Blended and Online Learning in Schools Graduate Certificate - https://education.gmu.edu/learning-technologies-schools/blended-and-online-learning-in-schools-graduate-certificate
- Georgia Southern University’s Online Teaching and Learning Endorsement - https://cogs.georgiasouthern.edu/admission/endorsement-online-teaching-and-learning-online/
- Kennesaw State University’s Certificate in Online Teaching - https://bagwell.kennesaw.edu/departments/itec/programs/online-teaching-certificate.php
- Kent State University’s Certificate in Online and Blended Learning and Teaching - https://www.kent.edu/ehhs/tlcs/etec/online-and-blended-learning-and-teaching-certificate
As a new normal establishes itself for K–12 educators following the COVID-19 pandemic, it is important to consider the increased role that blended teaching will play in the field of education. This role will require teachers to demonstrate the new dispositions and develop various blended teaching competencies. In this chapter, we share implications for preparing teachers to teach in blended learning environments. The chapter begins by highlighting research-based methods to identify and measure blended teaching competencies. Specifically, we describe a blended teacher competency framework used to create and validate the Blended Teacher Readiness (BTR) survey instrument. Additionally, we share a free book series based on the BTR framework that can help teachers develop the competencies necessary for teaching in blended environments. We then provide practical guidance and tools designed to help teachers as they work to develop blended teacher competencies and design/facilitate blended activities in their context.

INTRODUCTION

When schools closed in response to the COVID-19 pandemic, teachers and schools were ill prepared to take on the challenges that came with emergency remote teaching (ERT; Hodges et al., 2020). Since colleges of education and school districts had largely ignored prior calls to prepare teachers for the online learning environments (Archambault et al., 2016; Kennedy & Archambault, 2012), teachers were forced to learn on the job, resulting in one of the largest teacher professional development efforts in history.
While teachers and students have largely returned to the in-person classroom, teachers’ experiences during ERT have provided them a reason and an opportunity to innovate their practice rather than returning to business as usual. Teachers should take inventory of what went well during ERT and apply them to their in-person practice. Research has found that teaching online alone can improve in-person teaching (Dikkers, 2015; Lowes, 2008; Roblyer et al., 2009). Undoubtedly, many teachers have already used their ERT experience to become better in-person teachers. However, additional guidance can help teachers to make better use of their ERT experiences and newly developed skills.

We and our colleagues have conducted a series of studies to identify and measure blended teaching competencies. We have used our research findings to develop openly licensed resources in the hopes of helping teachers develop those competencies. In the sections that follow, we review our research in this area and then share how it can be used in practical ways to inform and improve blended teaching practices.

RESEARCH REVIEW

At a basic level, blended learning is a strategic combination of online and in-person learning activities. Blended activities combine in-person learning with opportunities to interact with peers, teachers, and/or content online. These online learning activities can provide learners with some control of their learning time, place, pace, path, and/or goals. Making the shift to blended teaching can be challenging because it requires teachers to develop competencies specifically for that environment. The first challenge can be identifying these blended teaching competencies. When researchers reviewed online and blended teaching competencies, the majority (57%) could be applied to any teaching environment. Another 30% of these competencies focused on teaching online or developing a digital skill, and only 8% focused on teaching by integrating in-person and online learning activities (Pulham et al., 2018).

Building on this work, Graham et al. (2018) developed a framework and survey focused on four core blended teaching competencies:

- **Online integration**: the ability to make and implement decisions related to effectively combining online and in-person learning as part of core instruction.
- **Data practices**: the ability to use digital tools to monitor student performance, activity, and learner profiles to inform choices about educational interventions.
- **Personalization**: the ability to implement a learning environment that allows for students’ customization of goals, pacing, and/or learning paths.
- **Online interaction**: the ability to facilitate online interactions with and between those in the classroom and outside the classroom.

The framework also acknowledges that teachers’ technological skills and attitudes or beliefs (i.e., dispositions) are foundational to their ability to implement these competencies (see Figure 1).

Analyses of K–12 blended teaching practices based on this framework have revealed these competencies to be important to blended teaching implementation (Short et al., 2021; Short, Hanny, et al., 2021).
In addition to identifying and measuring blended teaching competencies, we have used the blended teaching competency framework to publish openly-licensed resources for teachers (see Figure 2). For instance, we have created a free online book series (https://edtechbooks.org/k12blended_series) that includes specific editions for elementary education, English language arts, math, science, and social studies. More content-specific editions are coming soon. The book series has 17 authors, many of whom are current blended teachers, and features examples and short videos of best practices from 38 model blended teachers to help teachers envision what blended teaching/learning might look like in their contexts.
IMPLICATIONS

If you are looking to start on your blended teaching journey, or if you are currently a blended teacher looking to improve your practice, our research and resources can help. Specifically, we recommend that you follow three steps: (a) Take Inventory, (b) Curate Support and Resources, and (c) Think Big, but Start Small.

Step 1: Take Inventory

To travel on the path to successful blended teaching, you need to have a strong sense of direction/purpose and know what it will take to get there. As a result, it’s important to determine your purpose(s) for blended teaching by taking inventory of how blended teaching/learning could help you and your students. You should also take inventory of your current blended teaching readiness so that you can focus on the competencies that will help you to get to where you want to go.

Determining Your Purpose

Effective teaching includes a careful application of techniques, modalities, and pedagogies that encourage students to learn in a specific content area. Blended teaching is best used when it fulfills a specific purpose for your students and your content. One way to find that purpose is to look at the challenges you and your students face in a traditional in-person classroom. We refer to these challenges as problems of practice. Your problems of practice may include improving student learning, increasing access and flexibility, and promoting pedagogical efficiency (Graham et al., 2019).

Of these three, improving learning is often the most compelling. Problems of practice in learning can involve any of the following: improving pedagogy, meeting students’ social and emotional needs, fostering the 6 C’s (communication, creativity, critical thinking, collaboration, character, citizenship) (Fullman, 2013; Graham et al., 2019), incorporating the 7 P’s (participation, pacing, personalization, place, personal interaction, preparation, practice with feedback) into your instruction, or increasing access (Graham et al., 2019). See Figure 3 for a language arts example of each of these challenges.
Once you have determined a problem of practice, you can begin thinking about how blending your classroom can help you overcome a specific challenge.

**Determining Your Current Skills**

As you prepare for any journey, it is important that you take inventory of what you have and what you will need. Similarly, if you are to address your problem(s) of practice through blended teaching, you will need to take inventory of your current blended teaching strengths and weaknesses. We recommend that you start by measuring your current blended teaching readiness using the Blended Teaching Readiness (BTR) Survey (http://bit.ly/K12-BTR). When you do, your results will be displayed as a dial for each of the five competency areas. These dials can help you pick one or two of the competencies to initially focus on. As you work to develop the competencies, you can continue to take the survey to measure your growth. In fact, on the first page of the survey you can select the competency sections of the survey that you would like to take so that it is easier for you to focus on the questions related to your goals (see Figure 2).
Step 2: Curate Community and Resources

Once you have taken inventory of your purpose and skills, it is time to curate a community and the resources that you will need to be successful along your blended teaching journey.

Community

Your blended teaching journey will be more successful and enjoyable with the right team or partners. Reach out to an existing professional learning community (PLC) or build a new one that includes others who are seeking to make similar instructional shifts within your school or district content level team. Research has shown that this kind of support can lead to improved confidence and build the competencies, skills, and dispositions important to blended teaching (Azukas, 2019).

You may also wish to partner with a coach. Many organizations are adding technology coaches to support implementation. Leveraging this support can be powerful for overcoming challenges that may prevent the implementation of effective practices. A coach supporting blended teaching should follow the teacher’s lead regarding the support they desire, even if it focuses on content or skills outside of the coach’s experience. While a coach should be willing to support
teachers throughout their entire instructional design and implementation process, they should also be readily available for urgent technical support and willing to limit their involvement to whatever the teachers indicate they need (Jensen & Graham, 2023).

**Resources**

As you form your community, it may help to see what other communities have accomplished. To that end, there are many resources available to teachers looking for examples of blended teaching in practice. As previously mentioned, the K–12 Blended Teaching book series (https://edtechbooks.org/k12blended_series) was created by teachers, for teachers, and has content-specific editions that provide blended teaching tips, resources, and examples. Organizations like The Learning Accelerator (https://learningaccelerator.org/), also provide examples of how various teachers, schools, and districts have approached blended learning in the past. Lastly, some school districts have successfully made blended learning the norm in their schools, and provide resources to help others do the same. One such district is the Dallas Independent School District (https://www.dallasisd.org/Page/58918), which created a Personalized Learning toolbox to help schools adopt blended and personalized learning strategies (https://www.thepltoolbox.com/).

**Step 3: Think Big, but Start Small**

A well-known Chinese proverb states, “A journey of a thousand miles begins with a single step.” This is also true with your blended teaching journey. The possibilities that blended teaching offers are vast and varied. While it is important to understand your long term goals and vision, we recommend prioritizing a specific competency area or solving a particular problem of practice and starting small. Don’t try to do everything at once. Start with an activity or a unit, then gradually increase what you do as your skills and confidence grow. You may find it helpful to brainstorm and plan what you would like to accomplish with your blend while building your blended teaching competencies. To support your efforts, we have developed this roadmap. Those overseeing professional development for an organization may wish to use a simplified roadmap to address their vision and meet the specific needs of their teachers (Jensen & Graham, 2023). We hope that these resources are helpful as you continue your journey to developing and refining your blended teaching skills.

**REFERENCES**


APPENDIX

The following resources are freely available and are designed to assist teachers in developing their blended teaching competencies/skills.

<table>
<thead>
<tr>
<th>Resource Description</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open access book series on blended teaching</td>
<td><a href="https://edtechbooks.org/k12blended_series">https://edtechbooks.org/k12blended_series</a></td>
</tr>
<tr>
<td>The Learning Accelerator - provides examples of how various teachers, schools, and districts have approached blended learning</td>
<td><a href="https://learningaccelerator.org/">https://learningaccelerator.org/</a></td>
</tr>
<tr>
<td>Blended Teaching Roadmap - resource for teachers to guide them in the creation and organization of a blended teaching module.</td>
<td><a href="https://docs.google.com/document/d/1-zn1FG2GF_K3SOZGUHy1eekVPKrMFfX51ruHei8BMV0/edit">https://docs.google.com/document/d/1-zn1FG2GF_K3SOZGUHy1eekVPKrMFfX51ruHei8BMV0/edit</a></td>
</tr>
<tr>
<td>Simplified Blended Teaching Roadmap (ideal for those working with teachers as part of professional development related to blended teaching)</td>
<td><a href="https://docs.google.com/document/d/1fpqtazG6xeokvbb2fo3eR7rovWhoKP5ekJMJaJbJZJc/edit?usp=sharing">https://docs.google.com/document/d/1fpqtazG6xeokvbb2fo3eR7rovWhoKP5ekJMJaJbJZJc/edit?usp=sharing</a></td>
</tr>
</tbody>
</table>
Accessing and Integrating Openly Licensed Digital Materials for Teaching and Learning

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In our research, we have found that teachers do not always have access to textbooks, or they need to augment their textbook with digital materials to make content engaging for students. We have also found the greatest barrier for teachers accessing digital materials is knowing where to find them and making time to align them to the curriculum. It can feel overwhelming to open a browser and look for materials that align to the unit and are appropriate for the level or age of the learner. Unfortunately, the competencies needed for this type of digital literacy are largely taken for granted and teachers continue to pour out time and energy for little gain. To address these challenges, in 2022 and 2023 we delivered two six-month professional development programs with 16 urban and rural teachers in the Mountain West region of the United States to help them locate and integrate openly licensed digital materials (OLDM) in their classes. This chapter shares some of the products that we created for this program, namely 1) an open repository reference, 2) an authentic materials guide, and 3) a reflection worksheet to help teachers integrate OLDMs to their curricula.

INTRODUCTION

In our region of the U.S., many preK–12 teachers are lacking sufficient professional development opportunities in their discipline. This challenge is further exacerbated by growing trends to discontinue textbook adoptions leaving teachers with the burden to either create teaching materials and/or find them online. Both require time and training.

We, the authors, are university faculty and staff who have consistently and intentionally engaged with our in-service teacher community for the last decade. In 2016 we conducted a needs assessment where K–12 teachers identified the barrier of finding teaching materials aligned to new state standards. As a result, in 2018 we created the Pathways Project (PP) (https://www.boisestate.edu/pathwaysproject/), an Open Educational Resource that provides over 900 ancillary standards-aligned activities for preK–16 world language teachers. We have had over 350 active participants—undergraduates, university staff and faculty, and in-service teachers—who create, revise, and share PP activities.

In 2021, we were awarded a National Endowment for the Humanities (NEH) Digital Humanities Advancement Grant (DHAG) to evaluate the impacts of OER teacher development on 16 urban and rural K–12 world language teachers. This chapter shares some of the products that have resulted from this program, namely, 1) an open repository reference, 2) an authentic materials guide, and 3) a reflection worksheet to help teachers integrate OLDM to their curricula. Although our work has been rooted in world languages, we revised and remixed the resources shared in this chapter to make them accessible to all preK–12 teachers, regardless of discipline.

RESEARCH REVIEW

Open pedagogy is characterized by teachers and students co-creating high-quality OLDM shared freely online to benefit teaching and learning (Wiley et al., 2017). These materials typically take two forms: Open Access (OA), or they can be Open Educational Resources (OER), which permit others to use and modify them in what is known as the
“5Rs”: retain, reuse, revise, remix, and redistribute (Van Allan & Katz, 2019; Wiley et al., 2017). Research shows that teachers using OLDM and engaging in the 5Rs not only benefit by gaining teaching materials, but through the process also gain professional development known as OER-enabled Pedagogy.

Higher Education has primarily promoted OA and OER’s cost savings. However, scholars have demonstrated other benefits. For example, they can elevate diversity and student’s voices because educators integrate and/or co-create content that is more reflective of their students. Although universities have emphasized OER textbooks, Blomgren (2018) has found that K–12 teachers are more likely to use smaller scale materials like ancillary activities with greater appeal for teachers who have less autonomy or time to overhaul a curriculum to fit a textbook.

Unfortunately, research also shows that preK–12 teachers face obstacles integrating OA and OER because they do not know how to access them and, when they do, they are unsure about the quality (Beaven, 2018; Tang, 2020). Teachers need professional development to mitigate these barriers. To our knowledge, little research has measured the benchmark for OLDM professional development to impact preK–12 learning contexts. The research findings that will stem from the NEH DHAG will mitigate this gap in understanding and fortify the ways open education is promoted and supported in preK–12 teacher development contexts. In the meantime, this chapter delivers practical tools that emerged from this grant to help teachers understand what OLDM are and provides resources to guide teachers in accessing and integrating them, effectively.

**IMPLICATIONS**

Explore What Makes Digital Resources “Open”

First, it is important to clearly define what OA and OER are compared to other digital materials that are not openly licensed. One of the key hallmarks of OLDM is that they have a license that gives explicit permission on how to use them. The visual below comes from this one-page handout (https://scholarworks.boisestate.edu/sw_pubs/38/) and demonstrates how OA and OER materials differ from other types of free digital materials. In fact, the image underscores the fact that both OA and OER make up a small component of free online content.

**Figure 1**

*How to differentiate between free and open (OA and OER) materials online*

Figure 1 also demonstrates that OA and OER are indeed different in that OER permits users to modify the materials and share them with others whereas OA materials do not permit modifications or changes to the materials. Figure 2 below provides an example for how OA and OER differ centered on the topic of Anne Frank. The reader can see that the OA example allows the user to use and access it and share it with others whereas the OER example provides access to an editable copy that the user can modify (if needed). The latter, as one might imagine, is very useful to a preK–12 teacher who may wish to make adjustments to the questions/task according to the age of their students, for example.
OA and OER, or, OLDM (remember OLDM stands for “Openly Licensed Digital Materials”) have licenses that dictate how to share with others. However, we have found that open licensing can feel overwhelming for educators. This presentation (https://www.canva.com/design/DAFMawnOGFl/iuVm61qpSSpw2eqE6mFBNw/view#1) and accompanying video (https://youtu.be/CPLBUtNtP80) explain the fundamentals of open licensing. Additionally, Creative Commons (https://creativecommons.org/) is a website dedicated to helping OER users create a license and/or understand licenses. We highly recommend trying their “license chooser” (currently in beta testing) (https://chooser-beta.creativecommons.org/) which has helped us determine the license that best represents the way we want to share our materials.
2. Access and Integrate OLDM

Once you have a clear understanding of what OA and OER are, you can begin to envision how you can use these materials. Below, we include practical steps for accessing and integrating OLDM into your classroom to impact learning. Figure 3 is a visual overview of three steps that we have identified that help teachers access and integrate OLDM. Each of the three steps is explained in detail below (2.1–2.3).

Figure 3
Steps to accessing and integrating openly licensed materials for your classroom

1. Start with a bank of high quality open repositories. Take time to explore which ones best fit your content area.

2. Align material to your curricula and think about how you might integrate open access materials into your assignments and assessments. Use this revise worksheet to guide how you might adapt materials that are openly licensed.

3. Redistribute your lesson plans and projects using an open publishing tool.
2.1 Start With A Bank Of High-Quality Open Repositories And Digital Materials

An open repository is the first place you want to look for OLDM. Why? Repositories are like a shopping mall that houses stores organized by the items being sold. Shoppers can quickly and easily navigate their way around to make their purchases. Similarly, a repository contains links to the materials you need but unlike a shopping mall, you do not have to pay for anything! In addition, because they are digital, repositories make finding materials efficient by the way they group and/or organize materials. Many include search and filter functionality to help you drill down to find the content you want, quicker. While we cannot erase the time it takes to find OLDM, we can help you find the right ones quicker. Dedicating the time to explore and save the repositories that best fit your discipline will save you time in the long run. Figure five is a preview of our “OER Repositories Reference, Remixed for All Disciplines” which are teacher favorites. Access the full document here: https://docs.google.com/document/d/10mXTAA7NkhMZmuyJFgU96igsCS-C9DEeaf-kuTfDzhAk/edit?usp=sharing.

Figure 4
A preview of the OER repositories reference, remixed for all disciplines

<table>
<thead>
<tr>
<th>Ancillary Materials Site</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.C. Open Collective</td>
<td>Available supplemental materials include activities, assessments, course syllabi, discussion topics, lesson plans, projects, rubrics, and more.</td>
</tr>
<tr>
<td>MERLOT</td>
<td>Provides access to thousands of discipline-specific learning materials contributed by the member community.</td>
</tr>
<tr>
<td>OASIS</td>
<td>Allows search for OER from hundreds of sources. Developed by SUNY Geneseo’s M Ine Library.</td>
</tr>
<tr>
<td>Commons</td>
<td>A public library of OER with tools for content authoring &amp; remixing. Also provides collaborative workspaces for creating, curating, and discussing OER.</td>
</tr>
<tr>
<td>PiET</td>
<td>Over 150 interactive simulations and teacher-submitted activities for biology, chemistry, earth science, math, and physics.</td>
</tr>
</tbody>
</table>

In addition to open repositories, you can also search for realia or authentic materials using a basic search through Google. Figure 5 below is a preview of the guide that can help you identify and search for authentic realia to augment your classroom activities. You can access the full guide here: https://www.canva.com/design/DAFezGKPWdk/QIY1ejvQ0WBcc80LTc8K4A/view.
The value of authentic materials is to engage learners in real-world tasks or to pique their interest and understanding of the discipline through something that is used in everyday life. You might be thinking, “but I teach beginning learning and these types of OLDM are too advanced for my students”. One of the mottos we use in our discipline is “adjust the task, not the text”. In other words, start with an excellent text (i.e., the OLDM) and make pedagogical adjustments to the task to align the text to the level or course you are teaching. Adjusting the task, not the text, is one way you scaffold understanding for the learner.

2.2 Alignment: How To Integrate Oldm To Your Curricula

Once you have located the OLDM you like, you want to think about aligning and integrating these to your existing curricula. If you found an OER activity on one of the repositories above, you will probably want to customize it to fit your learning context (remember that because it is OER, you can customize it). Or, you might have found an excellent authentic material and now you want to build a task-based activity that has your learners explore/navigate it. For example, maybe you have a Spanish-English dual immersion class. First, you have your students investigate the science of sea turtles with story map (https://storymaps.arcgis.com/collections/178e4693e76f45efabc45f62fe02d739) and then you create a project based assessment to accompany it. This revise worksheet (https://docs.google.com/document/d/12_Fg7l2q1Stlw4l0mqMpaDlHHe50DEGl604othQip9Y/copy) was created to help teachers reflect and customize existing OER activities. It can guide you through the process of revising an OER activity you find on one of the repositories referenced in section 2.1, or it can help you create an OER activity using any of the authentic materials referenced in the guide in section 2.1.
2.3 Share Your Work with Other Teachers

Now that you’ve accessed and integrated an OLDM, we hope you share it and share it widely. Figure 6 below depicts the ethos of our community engagement with OLDM which is to grow materials to impact teaching and learning through sharing openly. We encourage you to reach for the final “r” in the 5r OER alliteration which is to “redistribute” or publish your work using an open platform.

Figure 6

“The More We Share, The More We Have (series 1/2)” by Pietro Soldi for Creative Commons & Fine Acts is licensed under CC BY-SA 4.0

REFERENCES


**SUGGESTED READING**


**APPENDICES**

**Appendix A: A Consolidated List of Resources Linked in Chapter**

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Link</th>
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<tr>
<td>Boise State Pathways Project</td>
<td><a href="https://www.boisestate.edu/pathwaysproject/">https://www.boisestate.edu/pathwaysproject/</a></td>
</tr>
<tr>
<td>Open Access and Education</td>
<td><a href="https://scholarworks.boisestate.edu/sw_pubs/38/">https://scholarworks.boisestate.edu/sw_pubs/38/</a></td>
</tr>
<tr>
<td>Incorporating Photos, Illustrations, Video, Audio, News Articles, and Infographics into your OER- Interactive Presentation</td>
<td><a href="https://www.canva.com/design/DAFMawnOGFI/juVm61qppSSpw2eqE6mFBNw/view#1">https://www.canva.com/design/DAFMawnOGFI/juVm61qppSSpw2eqE6mFBNw/view#1</a></td>
</tr>
<tr>
<td>Incorporating Photos, Illustrations, Video, Audio, News Articles, and Infographics into your OER- Video</td>
<td><a href="https://youtu.be/CPLBUtNP80">https://youtu.be/CPLBUtNP80</a></td>
</tr>
<tr>
<td>Creative Commons</td>
<td><a href="https://creativecommons.org/">https://creativecommons.org/</a></td>
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<tr>
<td>Creative Commons License Chooser</td>
<td><a href="https://chooser-beta.creativecommons.org/">https://chooser-beta.creativecommons.org/</a></td>
</tr>
<tr>
<td>Finding &amp; Integrating Open Digital Materials Reference Sheet</td>
<td><a href="https://docs.google.com/document/d/10mXTAA7NkhMZmuylvJFgU96tgsCS-C9DEcafkuTfDzhAk/edit?usp=sharing">https://docs.google.com/document/d/10mXTAA7NkhMZmuylvJFgU96tgsCS-C9DEcafkuTfDzhAk/edit?usp=sharing</a></td>
</tr>
<tr>
<td>Click Here! Authentic Materials, Digital Humanities and Openly Licensed Design Resources</td>
<td><a href="https://www.canva.com/design/DAFezGKPWdk/Q1Y1ejvQ0WBcc80LTC8K4A/view">https://www.canva.com/design/DAFezGKPWdk/Q1Y1ejvQ0WBcc80LTC8K4A/view</a></td>
</tr>
<tr>
<td>Unsplash</td>
<td><a href="http://www.unsplash.com">http://www.unsplash.com</a></td>
</tr>
<tr>
<td>Create, view &amp; edit bookmarks</td>
<td><a href="https://support.google.com/chrome/answer/188842?hl=en&amp;co=GENIE.Platform%3DDesktop">https://support.google.com/chrome/answer/188842?hl=en&amp;co=GENIE.Platform%3DDesktop</a></td>
</tr>
<tr>
<td>The Science of Sea Turtles</td>
<td><a href="https://storymaps.arcgis.com/collections/178e4693e76f45efabc45f62fe02d739">https://storymaps.arcgis.com/collections/178e4693e76f45efabc45f62fe02d739</a></td>
</tr>
<tr>
<td>OER Revise Template</td>
<td><a href="https://docs.google.com/document/d/12_Fg7I2q1Stl-w4l0mqMppeQdHre50DEGl604othQip9Y/copy">https://docs.google.com/document/d/12_Fg7I2q1Stl-w4l0mqMppeQdHre50DEGl604othQip9Y/copy</a></td>
</tr>
</tbody>
</table>

**Appendix B: Tools for Redistributing OER**

<table>
<thead>
<tr>
<th>Redistribution Tool Site</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="merlot.org" alt="Merlot" /></td>
<td>Merlot offers several options to share your materials with others. Select “Add a Material” to link to a Google Doc or other website. Use the “Content Builder” tool to create a website or create a “Course ePortfolio” to curate a collection of resources for a course.</td>
</tr>
<tr>
<td><img src="oercommons.org" alt="OER Commons" /></td>
<td>Use the “Contribute Web Link” option to contribute an existing, web-based material. Alternatively, use “Create Resource” to create your materials inside OER Commons, making it easy for others to save and revise using the Remix tool.</td>
</tr>
</tbody>
</table>
If you are interested in creating a longer form publication like a guide or a textbook, you may want to consider a tool like Pressbooks. Consider finding out if your institution or state offers a Pressbook license.

PubPub is a free, community-led tool for publishing materials. Simple to use, yet powerful, the site offers the ability to create pages and embed media.

Appendix C: Tips and Tricks to Guide Your Searching Online

1) Tip 1: Google Image Searching

Google image search can help you find a photo or graphic that has an open license! In the search bar, type the name of the material or content for which you are looking. Then, click the “tools” button, then “usage rights” and finally, click “creative commons licenses”. Below, you can see an example of a search for “black history month” with links to OLDM.

Figure 7

Example of a Google image search using the Creative Commons license option

Tip 2: Organize Great Online Resources with a Digital Bookmark

You can easily save sites you find useful by creating bookmarks on your chrome browser. This site (https://support.google.com/chrome/answer/188842?hl=en&co=GENIE.Platform%3DDesktop) shows you how to do this, step by step. We recommend creating an “open” bookmark folder to save links you like in one easy-to-access-place.
Tip 3: Attribute the Author with Copy and Paste

The last page in our authentic materials guide (https://www.canva.com/design/DAFezGKPWdk/Q1Y1ejvQ0WBe-c80LTC8K4A/view) includes online sites that are tools to help you create presentations. For example, one of our favorite sites is unsplash (www.unsplash.com) which provides an attribution link you can copy and paste into your slide deck or document once you download an image to use. Many OLDM sites have this function to help you provide attribution through copy and paste, which is a big time saver!

Author’s Note:

This work is supported by a National Endowment for the Humanities Digital Humanities Advancement Grant. Any views, findings, conclusions, or recommendations expressed in this chapter do not necessarily represent those of the National Endowment for the Humanities.
Perhaps more than ever before, teachers find themselves pulled in multiple directions when working to meet students’ curricular needs. Online education resource marketplaces such as Teachers Pay Teachers (TPT) have presented a lifeline to teachers seeking to locate relevant classroom activities quickly and easily. These marketplaces offer a way for teachers to buy, sell, and exchange educational materials designed for classroom use. Being able to exchange curricula created for and by other teachers may offer opportunities for collaboration among educators, mentorship for novice teachers, and the potential for financial gain. However, there are also concerns with their use; chief among them is the inconsistent quality of resources. In addition, online educational resource marketplaces point to more philosophical issues facing the teaching profession. Teachers are drawn to TPT because they are often under-resourced, isolated, overworked, or time-strapped. When already underpaid teachers use personal funds to purchase curriculum, sites like TPT may be less of a solution for teachers’ challenges and more indicative of systemic, policy-level problems facing education today. In this chapter, we provide an overview of research on online education resource marketplaces and offer a list of considerations teachers should make if/when using these sources. These recommendations include becoming informed about the risks and benefits of using online educational resource marketplaces, being skeptical when it comes to the many facets of accessing and using such sites, critically evaluating resources and then modifying them to suit needs, being careful with one’s money and time when using such sites, reporting harmful or low-quality resources, and taking action to challenge harmful policies and systems that are the root cause of many curricular marketplace challenges.

INTRODUCTION

Today’s teachers are used to turning to the internet to find educational resources for their classrooms. These may include lesson plans, classroom activities, entire units, worksheets, bulletin board materials, and more. As teachers are well aware, Teachers Pay Teachers (TPT; TeachersPayTeachers.com) is one of the most popular host sites (see Appendix A for a list of other online educational resource marketplaces). TPT asserts that two-thirds of teachers in the United States have used its resources. Its popularity has grown widely, especially during the COVID pandemic (Marcin, 2020). As professors of education and former secondary teachers, we have spent nearly a decade studying the phenomenon of online educational resource marketplaces like TPT and the “online teacherpreneurs” who create lessons to sell in these spaces (see Appendix B for more about online teacherpreneurs and the practice of online teacherpreneurship). We have observed that along with the growth of these platforms, the practice of online teacherpreneurship is complex and contains both opportunities and challenges.

On the plus side, teachers creating and sharing their tried-and-true classroom lessons may hold promise, particularly if they are talented designers. Teachers should be compensated for their ideas and creativity, and great lessons are meant to be shared far and wide. Also, teachers appreciate easy access to just-in-time, classroom-tested resources that can support their students’ needs.

However, there are also risks with using such platforms, such as the quality of materials, which can be inconsistent. Because anyone can market materials, their authenticity can also be questionable. Online educational resource market-
places also point to larger, more philosophical issues facing the teaching profession. Teachers are drawn to TPT because they are often under-resourced, isolated, overworked, or time-strapped. But when already underpaid teachers use personal funds to purchase curriculum, sites like TPT may be less of a solution for teachers’ challenges and more indicative of systemic, policy-level problems facing education today.

This chapter aims to offer teachers an overview of the online educational resource marketplace phenomenon, along with practical, research-based advice to consider when/if they choose to participate in such spaces.

**RESEARCH REVIEW**

Online teacherpreneurship can offer an approach to curriculum that may be more teacher-centered compared to textbook publisher materials. Innovative and creative instructional activities can be easily exchanged without the gatekeeping that can be a common practice among external, for-profit textbook publishing companies (Hodge et al., 2019). As a result, teacher-centered and teacher-led approaches to curriculum may be more accessible. In addition, some teacherpreneurs may offer assistance or guidance when it comes to the implementation of their activities, enabling teachers to get support from fellow teachers when they need it (Shelton & Archambault, 2019). It also can enable increased teacher collaboration with colleagues across the globe (Torphy & Drake, 2019), and initial findings suggest that student learning increases within classrooms where teachers curate online classroom material that is rigorous (Torphy et al., 2021).

Despite the potential opportunities, growing research focuses on the many challenges. Recent scholarship has raised serious issues regarding the quality of materials offered across multiple content areas (Harris et al., 2021; Polikoff & Dean, 2019; Rodríguez et al., 2020). It is difficult to determine the extent to which platforms monitor the quality of materials. In addition, platforms can display and manipulate visible metrics like ratings, reviews, popularity, and tags that users may rely upon to make purchase decisions – metrics that are not necessarily reliable (Shelton et al., in press).

Although the possibility exists to widen the exchange of teacher-created classroom activities, in actuality, substantial profits gained from such platforms are made by a small group of typically White women known as “power-sellers” (Sawyer et al., 2020). As a result, the practice may not be as equalizing as envisioned. Moreover, the system relies on the work of both buyers and sellers, not only to create and market materials but also to search for and evaluate/rate activities and purchase materials. These purchases often come from teachers’ personal funds. The work is unpaid on the part of teachers, and the practice depends on the labor and money of already underpaid educators to drive the marketplace platforms’ profits (Shelton et al., 2022). Because of these concerns, teachers should proceed carefully if and when they decide to purchase materials from online education resource marketplaces.

**IMPLICATIONS**

In what follows, we offer a list of suggestions for how teachers should approach online educational resource marketplaces.

1. **Become informed about the opportunities and challenges of using online education resource marketplaces as an approach to curriculum sourcing.**
   Before using these complicated spaces, it is important that teachers first understand the lay of the land. We suggest reading popular press articles (see Appendix C) for a simple overview of the pros and cons of online educational resource marketplaces. After learning more about these spaces, teachers should be able to make an informed argument for why they use (or choose not to use) these for-profit curricular marketplaces. Such arguments should address opportunities for collaboration, the value of teacher-created curriculum, quality issues, teachers’ use of personal funds, the labor teachers exert, and the profits marketplace platforms extract from teachers. Appendix C provides a list of popular press articles teachers should read to gain a cursory introduction to the opportunities and many challenges of online educational resource marketplaces.

2. **Be skeptical of user ratings, resource tagging, popularity indices, and featured reviews.**
   Research suggests that the metrics offered by online educational resource marketplaces are not valid or useful. For example, user ratings are overwhelmingly high across TPT’s millions of resources, yielding ratings scores uninformative. Also, resources are often incorrectly tagged, and over-tagging is widespread. For example, a resource may be
tagged as appropriate for middle school, but it was designed for 3rd grade. The credibility of popularity indices has also been questioned, as many studies have documented quality issues when examining the most popular resources. This problem has been found across content areas and grade levels, including math, English, and social studies. Critical online educational resource marketplace users will understand that these platforms’ primary goal is to make sales. Accordingly, platforms present and manipulate metrics like ratings, reviews, popularity, and tags. Buyers need to dig much deeper than these superficial metrics to determine if a resource is worth downloading and ultimately using with their students.

3. **Critically evaluate content creators.**

   Online educational resource marketplaces have a diversity problem when it comes to their content creators. For example, the majority of TPT sellers present historically privileged identity dimensions --- often presenting as White, cisgender, attractive women. We know that teachers’ lived experiences impact the lessons they design. So, as buyers, it is important to be intentional about who you purchase lessons from.

   In addition to identity, content creator’s expertise and qualifications are also important to consider. Qualifications are not clearly stated on most sellers’ digital storefronts. Any qualifications that are displayed are most certainly not verified. Savvy shoppers will need to dig deeper to investigate content creators’ credentials—perhaps Google searching or following the seller’s social media. Educators may want to take advantage of online communities (e.g., specific Facebook groups or similar), given that research suggests there is a potentially valuable online ecosystem created by teacherpreneurs and users. By following sellers online, educators can see how others modify and implement the materials, ask for the help of the content creator or other colleagues, etc. The Educators And Their #Community (Learning for Justice) blog post offers a window into how justice-oriented educators are finding community and solidarity with teacherpreneurs online.

4. **Critically examine resource content and pedagogical approaches.**

   Before implementing online educational resource marketplace material in your classroom, it is important to examine it thoroughly and critically. As noted, many studies have shown that TPT content is of inconsistent quality. Some excellent lesson materials are available, but there are also low-quality materials, including some that are racist, sexist, and/or historically inaccurate, among other problems. Savvy teachers will use rubrics to evaluate the material systematically. Because it can be hard to do this before purchasing, remember that on TPT, you can ask for a refund if the full resource is not what you expected. The following rubrics may be of use to critique resources found on online educational resource marketplaces: Pinning with Pause Rubric (Gallagher et al., 2019) and Curating and Creating with Care: History/Social Studies (Shelton et al., 2020). After critiquing the material, teachers should then modify the resource to meet their context, community, and student needs.

5. **Be careful with your money and time.**

   Research suggests that lots of time and money can be spent on the marketplace and surrounding social media. Teachers should ask themselves, is this worth all the time and effort? It is also important to consider how much money you are spending. Are free (possibly superior) resources available elsewhere? Free high-quality curricula can be found on numerous sites (see Appendix D for some suggestions).

6. **Report harmful online educational resource marketplace materials (to the platform and publicly).**

   If you come across harmful, inappropriate, or low-quality material on the marketplace, please, take action. On TPT, you can report any resource that violates their content policy via a few clicks on their website: How Do I Report A Resource on TPT?

   We also suggest directly reaching out to content creators and even publicly calling out inappropriate material. For example, Figure 1 shows a recent tweet by an elementary teacher who came across a TPT resource that inaccurately summarized Dr. Martin Luther King’s I Have A Dream speech. In a reply to this initial tweet, she also shared a screenshot of the message she sent directly to the content creator, introducing herself and explaining the “colorblindness and denial of racial identity” present in the worksheet. She goes on to ask, “I wonder if you’d see fit to revise or adjust the resource so as to better represent Dr. King’s message of justice and avoid potential misunderstandings, even from an early age” (Castellano, 2023). We see teachers posting similar questions and critiques of TPT material on Twitter and Facebook often and always appreciate the critical discussion (and hopefully action) that ensues. Another example of a critical and helpful voice in this space is Dr. Debbie Reese (@ debreese), an Indigenous scholar and educator who commonly calls out harmful educational material via Twitter. Reporting harmful material and reviewing it honestly can be valuable, but we also acknowledge that this requires your time and effort. You might ask yourself, how do I free about using a platform that relies on teachers’ unpaid labor to regulate its content?
7. **Take action to challenge harmful education policies that are the root cause.**

The final item we hope you consider is a little more philosophical – but important, nonetheless. Teachers’ attraction to online educational resource marketplaces illuminates the harsh realities facing the teaching profession – that teachers are underpaid, under-resourced, siloed, and overworked (Apple, 2013). On one hand, sites like TPT have offered a way to fund teacher curriculum creators while providing fellow under-resourced and time-strapped teachers access to the material and support they need. However, on the other hand, they may offer more of a band-aid than a viable solution. Flawed systems are really at the root of the problem. Rather than spending more time surfing TPT, teachers could work together to move toward changing harmful policies, such as schools’ disinvestment in curriculum or the role that elected officials play in education funding and teacher professionalism. It is up to us teachers to help our fellow teachers, parents, community members, and school/district leaders to understand these problems around poor curriculum and the lack of time that teachers have. It is up to us teachers to demand better and rally support for such changes. Building awareness is one way to start, and voting is another way to take action.
REFERENCES


Castellano, J. (@teachbk) (2023, April 3). Once again, TPT offers a useful teaching tool. Teachers can practice differentiating between intent and impact by asking themselves: What is the intention of this resource? What are some unintended outcomes? What can be done next? [Tweet]. Twitter. https://twitter.com/teachbk/status/1643090108327837697


APPENDIX A

Online Educational Resource Marketplaces Popular at the Time of This Publication

- Share My Lesson
- Lehrer Marktplatz (German Online Educational Resource Marketplace)
- Teachers Pay Teachers
- TES
- Twinkl
APPENDIX B

What is Online Teacherpreneurship?

Online teacherpreneurship refers to the practice of current and former preschool – 12th grade teachers sharing classroom resources and ideas online for profit (Shelton & Archambault, 2019). The following recent studies offer insights into online teacherpreneurs’ beliefs, experiences, and outcomes:


- Sawyer, A. G., Dick, L. K., & Sutherland, P. (2020). Online mathematics teacherpreneurs developers on Teachers Pay Teachers: Who are they and why are they popular? *Education Sciences, 10*(9), 248. [https://doi.org/10.3390/educsci10090248](https://doi.org/10.3390/educsci10090248)


APPENDIX C

Popular Press Insights into the Opportunities and Challenges Associated with Online Educational Resource Marketplaces

- A Sharing Economy Where Teachers Win *(New York Times)*
- Teachers Turn to Sharing Economy for Work Life Balance *(PBS News)*
- “I am a Scavenger!” The Desperate Things Teachers Do To Get What They Need *(Washington Post)*
- The Online Lesson Plan Marketplace Boomed When the Pandemic Hit *(Mashable)*
- Why Teachers Pay Teachers? *(ASCD)*
- Lesson Plan Platforms for Teachers Have a Racism Problem *(Slate)*
- On Teachers Pay Teachers, Some Sellers Are Profiting from Stollen Work *(Education Week)*
- What Teachers Pay Teachers Is Learning from Bad Lessons and Upset Teachers *(Ed Surge)*
- Teachers Pay Teachers: The Fast Food of Education *(The Educator’s Room)*
- New Hanover School District Apologizes for ‘Monopoly-like’ Slavery Game; NAACP Responds *(NBC News)*
- Four Strategies for Vetting Online Lesson Materials *(Educational Leadership)*
APPENDIX D

Free high-quality sources of vetted curricula

- Learning for Justice Lessons
- Morningside Center for Teaching Social Responsibility Lesson Collections
- The New York Times The Learning Network
- Public Broadcast Station Learning Media
- Smithsonian Learning Lab
- Zinn Education Project Teaching Materials
Classrooms With and Without Walls: Intentionally Blending In-Person and Virtual Learning Spaces

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In this chapter, we explore the ways that digital learning materials, experiences, and environments have become an integral part of learners' educational journeys. We review three principles from cognitive science and online learning research, and we demonstrate how these principles can be put into practice in K–12 classroom-based contexts for more intentional and effective, technology-enhanced teaching and learning experiences. The Welcoming Environment principle is practiced through several examples of student-friendly language, clear navigation, and a designated “Welcome” module. The Minimized Cognitive Load principle is practiced through consistent course structure and signposts that reduce the processing needed to navigate course expectations. Finally, the Multimodal Engagement principle is practiced through multiple modes of content access and engagement enabled by the learning management system. Each of these principles are easily implemented in virtual spaces for a more intentional application of digital learning as an extension of the in-person class. Examples from a high school chemistry course are used as demonstrations for each principle and starting points for teachers who would like to apply the principles to their own teaching.

INTRODUCTION

In the wake of emergency remote instruction and virtual teaching and learning that took place during the COVID-19 pandemic, many K–12 classrooms have become increasingly hybrid, with the online learning management systems and digital instructional content occupying a larger part of the day-to-day curriculum. Some teachers leverage a learning management system, like Google Classroom, Canvas, and others, while some teachers integrate occasional online resources into lessons or units of instruction. This usage can vary depending on available resources, department or campus climate, personal preference or bandwidth, among other factors. While this brings promise for equitable access to curriculum (Weaver, 2022), opportunities for innovative teaching approaches (Cirillo et al., 2020), and value in the student learning data to inform adaptive instruction (Torchia, 2022), most classroom teachers found themselves teaching online with little or no preparation for this type of intentional and complex instruction (Moore, 2022). As teachers continue to make use of the digital environments and materials they developed and used during the pandemic, there is a new opportunity to leverage research-based principles from cognitive science and online learning for technology-enhanced face-to-face instruction.

In this chapter, we review three principles from cognitive science and online learning, and we demonstrate how these principles can be put into practice in K–12 classroom-based contexts for more intentional and effective, technology-enhanced teaching and learning experiences. These principles are drawn from the work of online researchers, Nilson and Goodson (2018):

- Safe, low stress, supportive, welcoming environment
- Instruction designed to minimize cognitive load (less demand on working memory)
- Multimodal Repetition- process content in at least two or three modalities involving multiple senses (read, hear, talk, write…)

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For each principle, we review the cognitive science and online learning literature, examine educational technologies or technology-enhanced strategies for applying this principle, and share an example of the principle in practice. While the example course in this chapter makes use of a Learning Management System (LMS) to facilitate these principles, with some planning and creativity, these concepts can be applied to class websites, newsletters, or even shared folders (e.g., Google Drive; OneDrive) in lieu of an LMS because the principles are not technology or LMS-dependent.

**RESEARCH REVIEW**

It is important to understand that the principles framing this chapter are already considered best practices in traditional, classroom-based teaching. However, they are applied differently in online contexts and could be overlooked entirely if the virtual classroom space that now augments in-person teaching is, perhaps inadvertently, treated as a secondary space and a repository for instructional materials and assignments.

In *Online Teaching at Its Best*, Nilson and Goodson (2018) connect cognitive psychological research with scholarship of teaching and learning to articulate twenty-five principles of online teaching and learning. For this chapter, we draw from their work to focus on three principles as they apply to the online extension of in-person class experiences: welcoming environment, cognitive load, and multimodal repetition.

Nilson and Goodson’s *welcoming environment* principle states that classroom environment impacts student learning: “They are more likely to achieve the outcomes of the course, develop higher order thinking skills, [...] and be satisfied with the course, whether classroom-based (Cornelius-White, 2007; Granitz et al., 2009) or online (Lundberg & Sheridan, 2015)” (Nilson & Goodson, 2018, p. 80). Acknowledging that it is difficult to hold a lot of information in working memory, their *cognitive load* principle suggests teachers should “[...] package information for the most efficient processing possible” (Nilson & Goodson, 2018, p. 80). In lesson planning, this is *chunking content*; and in our online spaces, modular course design helps us build this kind of learning sequence. Finally, Nilson and Goodson (2018) echo multimodal research and universal design for learning (UDL) for their *multimedia principle*: “Students learn new material better and remember it longer when they receive it multiple times and in different ways [...]” (p. 81). With so many emerging, digital, academic technologies, the online space presents opportunities for enacting these principles.

**IMPLICATIONS**

**Principle: Providing a Safe, Welcoming Environment**

One of the first pieces of advice that many new teachers receive is to welcome students into the class (Wong & Wong, 1998). In person, this can happen with small moves, like a smile, a greeting, and use of their preferred names. One reason to leverage a learning management system (LMS) is because it can extend this idea of welcome to an online space that students and their supporters (e.g., parents; caregivers) can access in and beyond the class. The home page of the LMS helps to welcome and orient students to the important features of the online content. This course presents a clear welcome and place for students to start their learning. As the term continues, the *Start Here* buttons are removed and replaced with buttons to the weekly modules and the daily agendas. In this structure, the online course is the backbone and central nervous system of the course. Students know to access and interact with course content. The LMS is not simply a location for resources and assignment submissions. It is where they can find their learning activities to be completed in conjunction with the face-to-face instructional activities. Figure 1 provides an example of this kind of virtual landing space.
At the start of each year, students are provided with a Welcome or Start Here module that introduces them to several aspects of the course structure. Starting the year with this series of activities has two functions. First, students are given several low stakes tasks that will teach them the fundamentals of how to navigate the course structure and course content. Students are also introduced to the types of learning activities and assessments that they will complete during the term. Familiarity with the course structure, course navigation, and learning activities promotes a smoother start to the year. A final component of the Welcome or Start Here module are two elements intended to humanize the teacher and students. The About Your Teacher page provides a humanizing look at the teacher and communicates to the students relevant information about the teacher as a person. The final piece of the Welcome or Start Here module is the Welcome to Chemistry survey. In this task, students communicate with the teacher the answers to questions about preferred learning contexts, learning needs, time commitments outside of school, name pronunciation, and special interests. With the About Your Teacher and Welcome to Chemistry survey, students and teachers alike learn a little bit about each other, but within the context of the LMS helping to establish the connection between the face-to-face and online environments.

Another important feature of the initial course activities is a similar Welcome or Start Here module for parents and caregivers (see Figure 2). In K–12 educational settings, parents and caregivers are vital partners in the learning process for their students. As technology has increased in its classroom presence, so too has the number of platforms that students and parents must navigate. Providing parents with a clear understanding and concise explanation of what students will be doing, how their work will be graded, how to access content, and how to communicate can establish a connection between teachers, parents, and the content that promotes better success for students.

The activities contained in the Start Here or Welcome module help to show students their way around the course. Also, they serve the implicit function of demonstrating teacher presence in the LMS. The teacher provides narrated videos and also includes an “About Your Teacher” page. Though students will interact with the teacher directly in a face-to-face environment, purposefully including the teacher’s presence through videos and images can reinforce the notion that the LMS is integrated and inseparable from the in-person instruction. Figure 2 depicts content outlines for these simple but powerful modules. Further, these concepts can be applied to a set of Google Slides or pages, labeled and organized well in a shared folder or on a class website if they cannot be housed in an LMS. This concept of organization is expanded in the next section.
Principle: Instruction designed to minimize cognitive load (less demand on working memory)

One decision of course design that can minimize cognitive load is in how it is organized (Nilson & Goodson, 2018). For this course example in Figure 3 and Figure 4, content is organized into weekly modules. Each module opens on the first day of the week and assignments are due at the end of the week. The predictability of the structure removes this one
cognitive task for students of remembering when assignments are due. Also, each week as a general and consistent flow without being mechanical. The early part of the week is dedicated to introductory and engaging activities. The middle of the week tends to have activities geared toward processing and exploring the content. The end of the week is dedicated to intervention, support, and assessment.

**Figure 3**

*Screenshot of homepage buttons to navigate weekly modules*

The consistent structure of weekly content organization is a departure from traditional instruction that follows the scope and sequence of a textbook. Helping students think about their navigation through the virtual elements of our face-to-face course this way happens by revealing this implicit structure in the homepage navigation buttons (Figure 3) and the outline labels in the LMS Modules view (Figure 4).

**Figure 4**

*Weekly outline structure in the course modules view*
Though the course content is still challenging, student cognitive load is reduced by not asking them to remember and keep track of variable dates and learning structures. Students know what to expect for their learning on a given day. Figures 5–7 break down elements of a module overview page to further demonstrate this idea. In Figure 5, the purpose and topic of the week is introduced in student-friendly language. Figure 6 depicts a calendar with linked resources for use in class. This means that the LMS can become an extension of our in-class experience because the content is accessed and utilized virtually but we interact with it in real time and space. Figure 6 communicates which activities are consequential for learning, practice, and assessment.

**Figure 5**

*Module overview page with this week’s topic and informational notes*

**Module Introduction_Week 3**

**Welcome to Week 3!**

This week, we will be continuing our Combustion unit. Heat, Temperature and Energy are often confused with one another but have some important differences. We will learn about scientific modeling as a way of representing phenomena that occur at the microscale.

**General Notes**

- Unit 1 Dashboardneeds
- Most Week 1 Content Closes can’t be submitted after FRIDAY-September 9

**Figure 6**

*On module overview page, the weekly meeting schedule with day, date, topic, and in-class resources*

**Weekly Meeting Schedule**

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Topic</th>
<th>In-Class Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mon</td>
<td>8/29</td>
<td>Quiz: Week 2</td>
<td>CK12: Heat, Temperature and Thermal Energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Edpuzzle: Heat Transfer</td>
</tr>
<tr>
<td>Tues</td>
<td>8/30</td>
<td>1.3 Heat, Temperature and Thermal Energy</td>
<td>Explore: Modeling Heat and Temperature - Part 1</td>
</tr>
<tr>
<td>Wed/Thur</td>
<td>8/31-9/1</td>
<td>Quiz Retakes &amp; Re-submissions (Week 1 or Week 2)</td>
<td>Explore: Modeling Heat and Temperature - Part 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intervention Time</td>
<td>1.3 Heat, Temperature and Thermal Energy - PD</td>
</tr>
<tr>
<td>Fri</td>
<td>9/2</td>
<td>Tutorial &amp; Weekly Wrap-up</td>
<td>CK12: Heat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finish 1.3 Heat and Temperature PD</td>
<td></td>
</tr>
</tbody>
</table>
Principle: Multimodal Opportunities to Engage with Content

Both Universal Design for Learning and cognitive science research support the idea that students should have multiple means to engage with course content. In this particular module, students are tasked with understanding Heat, Temperature, and Energy, both at an introductory level but also in the relationships between them. These concepts can be confusing at even the highest levels of science education. The blended environment of the LMS allows students to engage with the content in a variety of contexts and modalities. For variety in learning context, students can access the learning activities at the pace of their learning. Whether they are absent, or wish to revisit an activity, students can have learning opportunities available when they need them. Likewise, students are offered multiple modalities to access the content. In Figure 8, students can engage with this concept via interactive reading (CK–12), video (EdPuzzle), in-class instruction (PearDeck), and lab exploration (Explore: Modeling Heat and Temperature). Each type of learning activity provides an access point for students based on how they learn best. Some benefit from a particular type of modality, but many will learn by accessing all of them. While the benefit of an LMS is some control around the learning sequence and some robust tools for teacher interaction, multimodal learning opportunities can be planned and sequenced in other digital spaces where a teacher might centralize digital class content.

The cognitive science principles described in this chapter—welcoming environment, cognitive load, and multimodal engagement—are already considered research-based best practices in both online and in-person class modalities as distinct and separate forms of teaching and learning. However, these principles apply to the blended, technology-enhanced class experience that so many teachers are trying to maintain following the few methods that worked well during emergency remote, and later virtual, teaching during the pandemic. Applying them takes some intentionality and design, as well as some resourcefulness with available resources, but the result is a cohesive and rich learning environment that combines the traditional classroom and new online learning spaces.
Figure 8

Module outline with multimodal engagement opportunities through video, reading, didactic lesson, and lab

<table>
<thead>
<tr>
<th>Week 3 (8/29-9/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Introduction, Week 3</td>
</tr>
</tbody>
</table>

**Lesson 1.3 - Heat, Temperature and Energy**

<table>
<thead>
<tr>
<th>CK12: Heat, Temperature and Thermal Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edpuzzle: Heat Transfer</td>
</tr>
<tr>
<td>1.3 Heat &amp; Temperature (In-Class Peardeck)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Explore: Modeling Heat and Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK12: Heat</td>
</tr>
</tbody>
</table>

**Week 3 Assessments**

<table>
<thead>
<tr>
<th>Week 3 Quiz</th>
</tr>
</thead>
</table>

REFERENCES


APPENDIX A: LIST OF FIGURES

This chapter contains 7 figures meant to illustrate practical applications from a science class and also to serve as models for teachers who would like to replicate these approaches in their own classes. Each figure is listed below with a link to view the .png file.

List of Figures

Figure 1: Screenshot of landing space with welcoming features for students and caregivers: Welcoming language and navigation buttons for Start Here modules

Figure 2: Side by side view of outline and contents for Student (left image) and Caregiver (right image) Start Here modules

Figure 3: Screenshot of homepage buttons to navigate weekly modules

Figure 4: Weekly outline structure in the course Modules view

Figure 5: Module Overview Page with this week’s topic and informational notes

Figure 6: On Module Overview Page, the Weekly Meeting Schedule with Day, Date, Topic, and In-Class Resources

Figure 7: On Module Overview page, alignment to outcomes, assignments, and formal assessments.

Figure 8: Module Outline with Multimodal Engagement Opportunities through video, reading, didactic lesson, and lab
APPENDIX B: RECOMMENDED WEBSITES

The following websites can help teachers apply the three principles from this chapter. This is a place to get started, but not an exhaustive list.

Principle: Providing a Safe, Welcoming Environment

- Canvas for Teachers - a free version of the learning management system. Requires [accounts].
- Wix.com - free class website.
- Infographic: How and Why to Humanize Your Online Class - applicable to online presence for face-to-face classes.
- Loom video - Tool for recording and posting teacher-created welcome videos, screen-sharing a tour of the online learning environment, and providing weekly, module, or unit overviews. Tip: include closed captions or a video transcript so that learners have multiple options for accessing this information.

Principle: Instruction designed to minimize cognitive load (less demand on working memory)

- Slides Mania - weekly agenda template for PowerPoint or Google Slides to provide students with all the links, content, assignments, and information they need on a day-by-day schedule. Can be embedded into the home page of an LMS or shared as a preview link.
- SEL at a Distance: Supporting Students Online, by Stephanie L. Moore

Principle: Multimodal Opportunities to Engage with Content

- CK12 - an open source library of complete digital textbooks as well as individual pages dedicated to specific concepts. Each concept has accompanying videos, simulations, and review questions.
- EdPuzzle - provide videos with embedded questions to students. Teachers can use videos already created by other teachers in the community or make their own. YouTube videos can also be converted into Edpuzzles with custom questions created by the teacher.
- PHET - created and hosted by the University of Colorado Boulder, this site contains free simulations and interactives to help students engage with math and science content. Simulations can be embedded onto an LMS page or posted as a direct link.

Recommended Resources for Further Reading

- Designing for Hybrid Learning - A 7-part series sponsored by the California Department of Education, CAST, and the California Collaborative for Educational Excellence.
- Course Map Guides - Downloadable course map templates, openly licensed by University of California, San Diego’s Teaching and Learning Commons, Digital Learning.
- Cult of Pedagogy - Teacher, Jennifer Gonzalez maintains a vibrant web presence with blog posts, podcasts, and videos about digital teaching and learning.
APPENDIX C: TEMPLATE FOR MODULE INTRODUCTION PAGE

Module Introduction Page Template (this link will prompt you to make a copy that you can customize for your classes)

Module Introduction Page Template

Introduction
Provide a brief introduction to the week’s concepts and learning. Explain the content of the learning in relation to what students have already learned or will learn next. You can also provide some explanation of relevance and how these concepts relate to student lives or fit into a broader aspect of their learning as students.

Resources
In this space, list any general class resources that students may need for the week, or in general.

Daily Schedule

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Topic(s)</th>
<th>In-Class Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>List the concepts and/or topics students will be learning.</td>
<td>List (with hyperlinks) any resources, handouts, assignments, etc. that students will need to access on this particular day.</td>
</tr>
</tbody>
</table>

| Monday |      |          |                                      |
| Tuesday|      |          |                                      |
| Wednesday|    |          |                                      |
| Thursday|     |          |                                      |
| Friday  |      |          |                                      |

Learning Objectives

<table>
<thead>
<tr>
<th>LO #</th>
<th>LO Title</th>
<th>Learning Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numbering learning objectives can help organize them into assessment and unit packages. In the example below 1.3 represents Unit 1, Lesson 3</td>
<td>A brief, succinct name for easy reference throughout the lesson</td>
<td>Student friendly statement describing the goal that all subsequent learning activities are aligned toward.</td>
</tr>
<tr>
<td>1.3</td>
<td>Heat, Temperature and Energy</td>
<td>Develop a model to explain the transfer of energy and the conservation of energy between a system and its surroundings</td>
</tr>
</tbody>
</table>
## Learning Activities

<table>
<thead>
<tr>
<th>Assignment Title</th>
<th>Category</th>
<th>Time Estimate</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide the name (with hyperlink if digital) to the assignment</td>
<td>If you use weighted categories, identify which category this assignment aligns to.</td>
<td>Provide an estimate of the time required to allow students to make informed choices about how to apportion their time for academic work.</td>
<td>Provide the point total (if relevant) for this assignment.</td>
</tr>
<tr>
<td>Explore: Heat and Temperature Labs and Projects</td>
<td>30-40 minutes</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>CK12: Heat, Temperature and Thermal Energy Preparation</td>
<td>10-15 minutes</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>EdPuzzle: Heat Transfer Preparation</td>
<td>10-15 minutes</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

## Assessments

<table>
<thead>
<tr>
<th>Assessment Name</th>
<th>Date</th>
<th>Points Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide the name (and link if virtual) to the assessment</td>
<td>When will students complete the assessment and/or when is it due?</td>
<td>How many points (if points are used) This could also be a place to provide a rubric if rubric-grading will be used.</td>
</tr>
<tr>
<td>Week 3 Quiz</td>
<td>Monday 9/5</td>
<td>8</td>
</tr>
<tr>
<td>Elaborate: Heat Transfer Model</td>
<td>Tuesday 9/6</td>
<td>10</td>
</tr>
</tbody>
</table>
Online tutoring in K–12 education is accelerating in school districts to fulfill needs brought on by the knowledge slide during the COVID-19 pandemic, retirement of baby boomers teachers, the need for supplemental instruction to meet state mandates, and the need for bilingual support. An elementary classroom teacher may have more students than ever, students with barriers impeding their learning. There are provided tools for teaching that might not be the right level/language for that student. Teachers also have fewer minutes in the day to accomplish it all. Those students are measured against all other students across the state at the end of the year, and their performance is a reflection on the teacher’s effectiveness and ability as an educator. The elementary classroom teacher is the key individual to the planning team for who, when, and how students receive tutoring is essential. The classroom teacher knows the student best and will provide the most insightful input about how the student learns, what content they do not comprehend, what their learning goals should be for the tutoring program, and how to motivate them while in the program. The classroom teacher should be a collaborator with the online tutor, sharing information about the student’s progress, and consistently monitoring for attainment of the end goal by the student so they are exited from the tutoring program with appropriate. The tutor planning team could also include a parent/guardian, school administrator, special educator, or other classroom aids as appropriate to gain optimum success from the tutoring program. Appendix A contains a select list of online tutoring companies.

**Keywords:** Online Tutoring, Elementary Math Instruction, Elementary Reading Intervention, After School Tutoring, Training Tutors, Tutoring Best Practices

**INTRODUCTION**

Online tutoring for K–12 students is found in research studies as early as the turn of the millennium. The root cause for online tutoring is the lack of teachers, the geographical isolation of some communities, the need for a specialist in subjects, bilingual support, and even for limitations of physical space in a facility. The reasons may differ, yet results are important to school administrators, classroom educators, students, parents, and taxpayers. Depending on the service provider, the number of students in tutoring, the subject level, and modality of the tutoring, the cost to the district varies.

For a school district to get the best results from a tutoring service, it must understand how the tutoring service works best, the training and certifications of the tutors, what the service can and cannot provide, which levels of students will experience the most gains from the service, and how classroom educators can prepare the students for a tutoring session in order to gain maximum impact.

The adoption of FEV Tutor (fevtutor.com) by a local school district provided the opportunity to view the process up close. Fifty elementary students (79% Latinx) were selected to receive after school tutoring via online tutoring four days weekly for an hour the entire school year. The cohort outperformed their untutored peers by 27% on state testing by May. Students received instruction in either math or reading, depending on their needs, and were often paired to ensure consistency between online tutoring and classroom teaching.
RESEARCH REVIEW

The research for online tutoring prior to the pandemic is valuable. Educators gained incredible experience from the COVID-19 lockdowns that are fraught with context to inform our new paradigm. Online mathematic support was studied Mullen et al. (2022) noting that pre-pandemic methods were largely drop-in support and scheduled one-on-one support. One finding in their literature review was that students needed to be within their Zone of Proximal Development for the tutoring to be effective, meaning that a student performing a grade level, or more, behind is less likely to benefit from online tutoring.

Ran et al. (2021) conducted a meta-analysis on published studies involving low-performing students using computer interventions. They found that a computer-based instruction tutor, “when combined with drill and practice, were more effective than computer tool programs” (p. 125). They also concluded a moderate effect of shorter interventions, such as a week to one month, as opposed to those lasting more than one year. A similar moderate effect in Ran et al. (2021) was the tutoring content: students who focused on basic mathematical facts had the largest effect than those who worked on problem solving.

The implementation of tutoring is not equal across schools – even within a district. Schools that are lower in socio-economic status, populated by students who are African-American or Latinx, are less likely to receive ongoing tutoring (Kraft et al., 2021). When these students are tutored, it is too often held after school and focused on the homework, instead of the skills.

A study by Vasquez and Slocum (2012) of students at risk of reading failure provided online tutors during the fourth grade participants’ homeroom or elective class time. The principal identified the teacher participants who then identified the at risk students in reading to be included in the tutoring program. The students received 50 minutes of supplemental virtual tutoring without missing core instructional time. Each participant outperformed expected gains from +9.2 words per week to +46.4.

The incorporation of a game into the tutoring was studied by Roschelle et al. (2020). The study included 144 fifth-grade students in a tutoring program about fractions lasting only 10-weeks, with two 25-minute sessions per week where students played the related FogStone Isle game. The pre- and post-test scores of the tutored students were statistically significantly higher on the t test with p value <.001.

IMPLICATIONS

Many school districts are motivated to implement strategies to improve test scores for students. The use of online tutoring, while expensive, is worth the investment to districts with complex issues. The key to adopting a tutoring service is understanding the district’s needs and goals then clearly communicating them to the service provider. Those might include the lack of teachers to provide the tutoring for bilingual and special education, space for 1:1 tutoring, time for tutoring, and the need for a highly specific discipline such as a mechanical engineering tutor.

Classroom educators need training on how to prepare the parents and students for the tutoring sessions. For conversation ideas with parents and guardians, refer to Appendix B. Simply sending the learner to the computer with the expectation that the tutor and student will figure it out is not likely to yield miraculous results. Providing the student, and the tutor, with an individualized plan for the session is optimal for success. When time is pressing, as it often is during the school day, a tailored plan is invaluable to the tutor working with the student(s).

Classroom teachers and school principals should consider using tutors during the school day instead of after school. Elementary students are tired by the end of the day and look forward to going home to play with friends, toys, or see family. Staying after school for tutoring might be a negative stigma for students in low-income areas or for students who are African-American or Latinx. The inclusion of a target for students to earn their way out of the tutoring is also important. Tutoring cannot be a life sentence, yet a short-term solution to rehearse skills for better performance on assessments. Eliminating the barrier of after school parent pickup, using the school day for tutoring and instruction, and rewarding students for reaching learning goals is critical for the success of the tutoring program.

Using the tutors to simply aid students in doing homework is not the best use of their time and skills. Online tutoring is an intervention strategy not a homework strategy. Many online tutors have bachelor degrees in their content and might be active or retired educators supplementing their income. The data and recommendations from previous research indicate to focus the content of online tutoring on basic or fundamental skills taught during the classroom lesson. Then apply the skills to a couple of sample problems or scenarios. The homework remains independent homework. The instruction
provided by the tutor is 1:1 assistance investigating the student’s understanding of the daily content lessons. What does the student know and where are her/his/their gaps? The goal is to locate the gaps, fill them in, and check for understanding with samples. This tutoring occurs in the classroom, not a large cafeteria or gymnasium with a single teacher watching over a hundred tutelage students. The student’s teacher knows the learning needs of the student best and can assist if the student is off task.

Tutors could use the Socratic Method of questioning to lead students during their online session. The Socratic Method is simplified into six kinds of questions used by the tutor. Here are the six categories with sample questions for reading comprehension:

2. Challenge assumptions – “Is this always the case? What assumptions have you made?”
3. Use evidence in arguments – “What evidence do you have for this? Is there reason to doubt this evidence?”
4. Exploring alternative perspectives – “What else could answer this? What is the counter-argument?”
5. Consider Consequences – “Then what would happen? What would happen if … didn’t do this?”
6. Question the question – “What other questions could I ask? Why is this question important?”

Students performing more than two years below their grade level in math and reading are less likely to improve with online tutoring. Previous research indicates those who benefit are often within the Zone of Proximal Development (Vygotsky, 1978). The Zone of Proximal Development is the area where students cannot do tasks alone, but can with the assistance or encouragement of an educator. If the student can accomplish the task without assistance, then the task is too easy. If the student cannot complete the task even with the intervention of the educator, then the task is too difficult.

An online tutor can assist students in learning material that is within their Zone of Proximal Development. For some learners, the tutor’s assistance might be minimal, while others might need focused instruction. As long as the learners understand the lesson, they are described as within their Zone of Proximal Development.

Students performing more than two years below grade level are not likely to achieve success since they cannot understand much of a lesson without prior knowledge. No matter the time of day the tutor meets with the student, the relationship the student builds with the tutor over time, the competency of the tutor as an educator, or the motivation by the tutor and classroom teacher to succeed, the likelihood of that student “catching up” on standardized testing is not possible due to the severe learning gap that exists to their peers.

Students in lower elementary, preK–2 are the least studied in online tutoring and likely for a reason. They lack the focus on the computer or tablet, nor have they developed the writing or typing skills to communicate on the computer with the tutor when needed. Their short attention spans with a computer or tablet make it far too exciting to explore and click around the screen instead of focusing on the tutor and the task at hand.

Online tutoring in K–12 education is an effective method to supplement the teacher shortage, facilitate time constraints, and ameliorate bilingual instruction options. State legislatures have enacted mandates for school districts to make up time with struggling learners, such as the Texas bill HB 4545 delineating extra instruction either before/after school, in groups of less than three, yet preferably 1:1 by a certified educator. The use of an online tutor is an effective solution to the challenge of meeting these state mandates. While the districts invest in these services, the classroom educators need to be included in the conversation on how to effectively implement tutoring so students receive the best outcome possible.

REFERENCES

FEV Tutor. (2022). Travis Elementary School uses FEV Tutor to raise students’ MAP Scores. www.fevtutor.com


**APPENDIX A**

**Select List of Companies Offering Tutoring Services to School Districts**


FEV Tutor – [www.fevtutor.com](http://www.fevtutor.com)

Hey Tutor – [https://heytutor.com/partnerships/](https://heytutor.com/partnerships/)

Paper Online Tutoring – [www.paper.co](http://www.paper.co)

Sylvan Learning – [https://www.sylvanlearning.com/](https://www.sylvanlearning.com/)

Tutor – [www.Tutor.com](http://www.Tutor.com)

Tutor Me High Impact Tutoring – [www.TutorMe.com](http://www.TutorMe.com)

**APPENDIX B**

**Parent/Guardian Conversations**

Placing students in online tutoring is a process. Teachers will look at the student’s scores and abilities to determine if the student needs the intervention. A decision is then made between the teacher and school administrator if the student should be placed in online tutoring. A best practice is to follow this decision convening a meeting with parents or guardians for a conversation about the importance of the intervention. The State of Texas has a state law that requires students who have not passed the Texas standardized state test to have 30 extra hours of tutoring intervention in the failed subject.

The principal, teacher, and parent meet and discuss the student progress and how the online tutoring will help the student be successful. The teacher will share what standards she would like the online tutor to work on. The teacher will explain to the parent what to expect in the tutoring program. The program will focus on Math or Reading and students will work on certain things depending on what they are scoring low on. The student will start with a test to show what they know and what they need to work on. If the student is mastering their standards they will continue to the next standard that needs help.

Over the course of the semester, parents will be kept updated by the teacher on student progress. Students are kept in online tutoring until goals are met and exited once the tutoring goals are complete. At the beginning of each school year, student performance scores from standardized tests are evaluated from the previous year to determine the need for tutoring in the new academic year. Parents sign a note of consent for students to attend tutoring and are kept up to date with the progress of their student.