INTEGRATING EDUCATIONAL TECHNOLOGY INTO TEACHING

TRANSFORMING LEARNING ACROSS DISCIPLINES

NINTH EDITION

JOAN E. HUGHES | M.D. ROBLYER

Integrating Educational Technology into Teaching:

Transforming Learning Across Disciplines

9th Edition

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Retired

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For all educators, including those in my family: my mother Judith Hughes (retired middle school teacher and vice-principal); siblings Deidre Hughes (community college professor), Thomas Hughes (high school teacher), Eileen Hughes (former high school teacher), and brother-in-law Craig Holliday (high school teacher); niece Margaret Hughes (paraprofessional); and parents-in-law Diane Stehr (retired all-grades special education teacher) and Paul Klancher (retired high school teacher).

—JEH

For Bill and Paige Wiencke, whose love is, as Arthur Clarke said of advanced technology, indistinguishable from magic.

—MDR

About the Authors

Joan E. Hughes has been a technology-using educator and contributor to the educational technology field for nearly 30 years and has authored or coauthored more than 100 publications, including books, book chapters, journal articles, proceedings, and research and practitioner conference papers worldwide.

After earning a bachelor of arts degree in English from Pomona College, she began working in the educational technology field as an elementary and middle school computer teacher in the Silicon Valley area of California in the early 1990s. As a classroom teacher, she presented often at the CUE Conference (known then as Computer Using Educators) and coauthored (with Terry Maxwell) her first book, *The CompuResource Book*, a collection of technology-supported lessons. Later, she pursued her doctorate in educational psychology with emphasis on cognition and technology at Michigan State University where she taught courses for preservice teachers in Michigan and inservice teachers internationally in Korea, Japan, Thailand, and England. Her earliest doctoral research developed the concept of technological pedagogical content knowledge, a theory generated from case studies of English teachers' learning and use of technologies in schools. This theory has been adapted and adopted widely.

Currently, Dr. Hughes is Associate Professor of Learning Technologies at The University of Texas at Austin where she conducts research and instructs on how teachers and K–12 students use technologies in and outside the classroom for subject-area learning; how school leaders support classroom technology integration; and how educators are technological innovators and valuable contributors in the edtech ecosystem. She serves on editorial and review boards for several teaching and technology journals and has contributed to leadership of technology-related special interest groups. She is highly supportive of her students' educational objectives and has guided 56 doctoral and 56 master of arts and master of education degree students to complete dissertations, theses, or reports.

She is married to Lee Klancher, a writer, photographer, and publisher (Octane Press). They spend time exercising their dog (currently, an adopted German shorthaired pointer named Red Cloud), running, biking, cooking, eating, and camping in Austin and around the world.

M. D. Roblyer was a technology-using professor and contributor to the field of educational technology for 35 years. She authored or coauthored hundreds of books, monographs, articles, columns, and papers on educational technology research and practice. Her other books for Pearson Education include *Starting Out on the Internet: A Learning Journey for Teachers*; *Technology Tools for Teachers: A Microsoft Office Tutorial* (with Steven C. Mills); *Educational Technology in Action: Problem-Based Exercises for Technology Integration*; and the most recent text, *Introduction to Instructional Design for Traditional, Online, and Blended Environments* (2015).

Dr. Roblyer began her exploration of technology's benefits for teaching in 1971 as a graduate student at Pennsylvania State University, one of the country's first successful instructional computer training sites, where she helped write tutorial literacy lessons in the Coursewriter II authoring language on an IBM 1500 dedicated instructional mainframe computer. While obtaining a doctorate in instructional systems at Florida State University, she worked on several major courseware development and training projects with Control Data Corporation's PLATO system. In 1981–1982, she designed one of the early microcomputer software series, *Grammar Problems for Practice*, for the Milliken Publishing Company.

Dr. Roblyer retired in 2015 after having served as a teacher, professor, graduate student mentor, doctoral student dissertation chair and committee member, and leader in shaping educational technology's changing role since 1969. She lives in Chattanooga, Tennessee, and is completing work on a memoir of her early life. She is married to fellow Florida State alumnus Dr. William R. Wiencke and a proud mother of daughter Paige Roblyer Wiencke.

Preface

About This Book

During a time when nearly everything else is changing rapidly and radically, the mission of this textbook has remained steady and consistent: to reflect the burgeoning, evolving role of technology in education. The book's 25-year history has always documented new and significant transitions in the role of technology in education, and the ninth edition continues that work. This edition continues its commitment to developing teachers as technology leaders, prioritizing transformative technology integration in the classroom, emphasizing unique affordances of technology for 12 content-area disciplines, and positioning all practices in relation to contemporary educational research perspectives. This edition also launches keen attention to the current issues of digital inequity in our society that influence children's educational success.

The text includes four sections that position the reader as a teacher learner and leader of transformative technology integration. The first section provides a definition of educational technology and the historical underpinnings of the field that inform our current practices, the learning theories that shape pedagogy, and a technology integration planning model that guides teachers to design technology-supported pedagogy that is responsive to instructional, curricular, or learning challenges. It provides the foundation for teachers to problem-solve, learn and lead through online networks, build a compelling online professional identity, and employ a professional rationale for using technology in all decision making. The second and third sections introduce the technological resources that support teaching and learning. The second section focuses on the digital content teachers and students use for learning. It reviews the content available on the web as well as within instructional software. These chapters also provide helpful evaluation criteria for use in reviewing and selecting digital content for adoption. The third section presents the digital resources that facilitate critical thinking, design, analysis, creation, communication, and collaboration. Ultimately, educators use all these digital resources to build blended or online learning lessons or curricula. The fourth section continues this book's commitment to technology integration in content-area disciplines with a chapter specific to the following content areas: special education; English and language arts (ELA); second and foreign languages; science, technology, engineering, and mathematics (STEM); social studies; music and art; and physical and health education. We go well beyond describing the technical features and capabilities of 21st-century digital resources to focus steadfastly on the research-based teaching and learning strategies that these resources can support in content areas.

The purpose of this book is to show how teachers can shape the future of technology in education. How teachers respond to this challenge is guided by how the authors see it helping educators accomplish their own informed vision of what teaching and learning should be. Our approach to accomplishing this rests on four premises:

1. **Integrating educational technology should be based in learning theory, teaching practice, and curriculum.** There is no shortage of innovative ideas in the field of educational technology; new and interesting methods come forth about as often as new and improved gadgets. Those who would build on the knowledge of the past should know why they do what they do as well as how to do it. Thus, various technology-based integration strategies are linked to well-researched theories of learning, and we have illustrated them with examples of successful practices based on these theories.
2. **A combination of technological, pedagogical, and content knowledge optimizes technology integration.** This textbook maintains that teachers not only need to

know the content they are teaching and good pedagogical strategies for connecting students with content, but also must recognize how to integrate technology into pedagogy to achieve the greatest impact on desired outcomes. In other words, teachers need what the field now refers to as technological pedagogical content knowledge, TPCK, or TPACK (described in Chapter 3).

3. **Uses of technology should match specific teaching and learning needs.** Some technology resources have the power to improve teaching and learning. Therefore, each resource should be examined for its unique qualities and potential benefits for teachers and students. Teachers should not use a tool simply because it is new and available; each integration strategy should be matched to a recognized need. Teachers should absolutely experiment as long as they begin with a problem of practice and carefully evaluate the outcome. The Technology Integration Planning model introduced in Chapter 3 guides teachers in this process.
4. **Old integration strategies are not necessarily bad; new strategies are not necessarily good.** As technologies change and evolve at lightning speed, there is a tendency to throw out older teaching methods with older machines. Sometimes this is a good idea; sometimes it would be a loss. Each of the integration strategies and technology resources recommended in this book are based on methods with proven usefulness to teachers and students toward solving learning needs rather than its age.

The goal of this edition is for teachers to see more clearly their leadership role in shaping the future of technology in education. This book illustrates that great education means employing technologies to fulfill the vision they make possible—a worldwide social network and a global community that learns and grows together.

What's New in the Ninth Edition

Best known for its technology integration strategies grounded in strong research, the ninth edition of *Integrating Educational Technology into Teaching: Transforming Learning Across Disciplines* offers a total technology integration framework across all content areas. It also gives teachers practice with technology resources as they learn how to incorporate technology to support curriculum in ways that transform instruction and learning. And as usual, this edition includes additions that reflect changes in the field of educational technology.

- **A NEW Focus on Digital Equity.** Each chapter includes a key feature highlighting a digital equity issue relevant to the chapter's thematic content, such as definitions of digital equity and justice; ways to use technology for equitable learning practices; an overview of the universal design for learning framework; current statistics on Internet access in students' homes; ways to move from inequitable, passive digital practices to humanized and empowered digital learning in classrooms; and examinations of the representation of minoritized children (e.g., girls, students of color, students with learning needs, and students of lower socioeconomic means) in digital innovation learning contexts like makerspaces and in online learning opportunities. We also provide practical suggestions for teachers to take action to examine each issue in locally relevant ways.
- **A NEW Commitment to Social Constructivism.** In Chapter 2, the text provides an exhaustive review of both directed and social constructivist theories and beliefs and describes how these contribute to differing pedagogical strategies with technology because both approaches exist within K–12 schools. Yet, throughout the text, the authors predominantly exemplify technological pedagogy in alignment with social constructivism because these approaches situate children in agentic,

active, and hands-on learning with technologies. All chapters open with a richly described *Technology Integration in Action* scenario and include several *Technology Integration Example* lessons throughout, all aligned with the chapter's thematic content and crafted to help teachers discern the value of social constructivism in digital learning.

- **A NEW Acknowledgment on Technology's Role in Local and Global Disasters.** Chapters highlight how technology can exacerbate or ameliorate educational challenges during global disasters, such as our current COVID-19 pandemic, and during local disasters, such as forest fires, hurricanes, tornados, floods, and earthquakes. Examples describe how the pandemic illuminated the entrenched digital inequities in our society, such as lower access to broadband Internet and home computing devices by many families in our communities, that decreased their access to education when separated from physical school buildings. On the other hand, access to digital technologies, high-speed Internet, and high-quality online learning experiences help maintain children's access to education during such physical separations. The overall goal of the text is to prepare teachers to be pedagogically ready to plan and teach in blended and fully online modalities, while also anticipating and advocating for students who may experience issues with digital access.
- **NEW Research Perspectives.** Every topic in every single chapter reflects the newest educational research perspectives since 2016, when the last edition of this text was published. We conduct comprehensive reviews of the research literature to ensure that our practical recommendations for teachers are research based. This research directly informs the chapters' sections that review the benefits, challenges, integration strategies, and selection or evaluation criteria related to the myriad of digital resources included in the text. While the idea of "research" may seem distant to classroom practitioners, it is important to remember that all educational research occurs in classrooms in collaboration with children and their parents and teachers and school leaders. Research allows us to understand educational practice and perspectives in collective and organized ways so teachers can glean insights from those who have come before them.
- **NEW Examples and Videos.** This text reflects real educational technology practices in real schools. Chapters include numerous new technology integration ideas, lessons, perspectives, and videos exemplifying the reviewed digital resources and pedagogical approaches. These depicted technology integration practices are sourced from practitioner magazines, conferences (such as ISTE), teacher blogs and tweets, and from the research literature. New videos are organized to match the chapter's thematic content and are sourced from real classrooms and from YouTube videos published by nonprofit organizations, schools and teachers, and educational technology companies.

Key Content Updates by Chapter

- **Chapter 1.** Updated the definition of *educational technology* and the *integrating educational technology* framework that aligns with the Technology Integration Planning (TIP) model introduced in Chapter 3 and used throughout the book; added the *digital justice* era into the depiction of educational technology across time; updated the emerging digital resources and trends in blended and online learning, games and gamification, personalized learning, maker and DIY, computational thinking, and immersive learning; added information about digital privacy, health and well-being, digital identity, and digital equity and justice in the conditions that influence the environment for using technology.

- **Chapter 2.** Reorganized the learning outcomes to align with the first triangle of the *integrating educational technology* framework that focuses on educational processes—learning theories, pedagogy, and curriculum/content—as introduced in Chapter 1; removed multiple intelligences theory; added a description of critical pedagogy and its implications for practice and for technology integration; added descriptions of each of the most current ISTE Standards for Students (2016); and added new Technology Integration Examples.
- **Chapter 3.** Reorganized the first learning outcome to align with the second triangle of the *integrating educational technology* framework that focuses on technology resources–technology tools, technology expertise, and technology support–as introduced in Chapter 1; added an author-designed survey for teachers to gauge their expertise based on the most current ISTE Standards for Educators (2017); updated sections on how teachers can become and the value of being connected learners through online networks; updated the TIP model (previously in Chapter 2), which guides teachers in planning technology-integrated lessons from an asset-based orientation and includes the RAT assessment model for determining relative advantage of technology in lessons.
- **Chapter 4** (previously Chapter 6). Relocated as the first chapter of Part 2, Digital Content for Learning; added lateral reading as a strategy for online information literacy; added a digital well-being section to safety and security; added digital justice issues related to use of online proctoring software; updated all technological resources to the most current.
- **Chapter 5.** Reordered the instructional software by its predominant alignment with directed (learning outcome 5.2) or with social constructivist learning theories (learning outcome 5.3); added a new Technology Integration in Action scenario at chapter opening; updated all technological resources to the most current; described perspectives that frame some instructional software as deficit-based and dehumanizing; included a comparison table of aspects of humanized and dehumanized personalization built into instructional software; added cautionary information related to use of simulations or games that involve content involving racial and social oppression.
- **Chapter 6** (previously Chapter 4). Relocated as the first chapter of Part 3, Digital Resources for Critical Thinking, Creating, Communicating, and Collaborating in Blended and Online Contexts; reframed the learning outcomes to be about the learning activity (e.g., writing, representing, analyzing) rather than the technological software; added a table summarizing how a design process is involved in the digital learning activities under focus; updated all technological resources to the most current; added new Technology Integration Examples; updated and integrated assessment activities into a data collection, analysis, and assessment section (learning outcome 6.3)
- **Chapter 7.** Updated learning outcomes to focus on the digital activities of communicating, collaborating, and making; added a table summarizing how a design process is involved in the digital learning activities under focus; updated all technological resources to the most current; added new Technology Integration Examples; added parent communication and collaboration strategies; added multifunction workspaces (e.g., Slack, Microsoft Teams); updated information on learning management systems; updated section on digital making, including computer programming, robotics, 3-D modeling and animation, game and app development, virtual world and augmented reality development, and web design and development.
- **Chapter 8.** Added a representation of the key terms used across the continuum of in-person learning to blended and online learning modalities; updated the descriptions of the seven blended learning models; described ways in which low

home access to digital resources impedes access to blended and online learning; updated the online course models; added a section on the varied combinations of in-person, blended, and online learning (sometimes called "hybrid") that schools implemented during the pandemic; added an author-created list of discussion forum content category tags that support student metacognition and rich online discussions; updated all technological resources to the most current.

- **Chapter 9.** Updated the number of students with disabilities currently being served for special education across schools; updated the laws and policies that impact the use of technologies for special education purposes; added a section on the universal design for learning framework and how it can be used to guide design of online learning; acknowledged how the COVID-19 pandemic's reliance on online learning negatively impacted many students with disabilities; added a digital equity and justice issue concerning how technologies can limit accessibility to digital information; updated the *Top Ten Must-Have Special Education Technologies*; updated Twitter hashtags to follow for networked learning; updated all technological resources to the most current.
- **Chapter 10.** Updated the competencies of digitally literate learners; added a digital equity and justice issue concerning income-based online reading achievement gaps; updated all statistics related to print and digital reading patterns; updated the *Top Ten Must-Have Technologies for English and Language Arts*; added new Technology Integration Examples; updated Twitter hashtags to follow for networked learning; updated all technological resources to the most current.
- **Chapter 11.** Clarified terms related to English learners who may already speak multiple languages, thus learning English is not necessarily their *second* language; updated the characteristics and diversity of the English learner population and described four groups of learners; updated the importance of involvement of content-area teachers in students' academic and language development; added a digital equity and justice issue concerning inclusion of parent perspectives from new immigrant families in school- or home-based technological adoptions; updated the *Top Ten Must-Have Technologies for Language Learning*; added a section on online learning; updated Twitter hashtags to follow for networked learning; updated all technological resources to the most current.
- **Chapter 12.** Updated opening section that distinguishes STEM content, context, and tool/application integration instruction; added a digital equity and justice issue concerning inequitable outcomes on a national assessment of eighth-grade students' technology and engineering literacy; updated section on using technology to support NGSS-aligned scientific discovery; updated the *Top Ten Must-Have Technologies for STEM Instruction*; updated approaches to engineering education through makerspaces, programming, robotics, and simulations; updated recommendations for teachers to use mathematical action technologies in alignment with social constructivism; added section on developing students' data literacy; updated Twitter hashtags in science, engineering, and mathematics for teachers to follow; updated all technological resources to the most current.
- **Chapter 13.** Added a new section on the need for and challenge of achieving diversity, equity, and inclusion in social studies; added new lesson resources for helping students assess quality of informational sources; added a digital equity and justice issue concerning how extended reality technology resources, such as virtual and augmented reality experiences, may introduce barriers for students with some disabilities; updated the *Top Ten Must-Have Technologies for Social Studies*; new Technology Integration Examples; new section on online learning in social studies; updated Twitter hashtags for teachers to follow for networked learning; updated all technological resources to the most current.

- **Chapter 14.** Added a digital equity and justice issue concerning the need for greater inclusion of musical and visual art content genres beyond the canons of "fine art" in education; added a section about ethical issues for music educators; updated the *Top Ten Must-Have Technologies for Music and Visual Arts Instruction*; added a new section that situates the impact of technology on the visual arts in education and society; added a new section on design and innovation in visual art education along with a design process for students to pursue projects in the visual arts; added a new section about the need for inclusion of creations by marginalized populations; added a new section on integrating visual art with other disciplines; added new Technology Integration Examples; updated section on artistic and design creation; added section on teaching visual arts online; updated Twitter hashtags in music and visual arts for teachers to follow for networked learning; updated all technological resources to the most current.
- **Chapter 15.** Updated physical activity, diet, and obesity trends to reflect the most recent data; updated section on national standards and barriers to quality health and physical education programs; Added a digital equity and justice issue concerning hunger and food insecurity, with practical suggestions for using digital tools for community walks and equity audits of the food landscape so teachers can best advocate for learners; updated the *Top Ten Must-Have Technologies for Health and Physical Education*; reorganized integration strategies into sections about improving instructional effectiveness, maximizing practice opportunities, providing feedback and assessment, monitoring physical activity and nutrition, accommodating students with special needs, helping students find valid online information, influencing health behaviors beyond school, and providing online modalities for health and physical education; updated Twitter hashtags for teachers to follow for networked learning; updated all technological resources to the most current.

Pedagogical Features of This Text

For the ninth edition, the authors maintain a cohesive, comprehensive technology integration framework that builds on strong research and numerous integration strategies. This Technology Integration Framework achieves the following goals:

Introduces Teachers to Technology Integration

TECHNOLOGY INTEGRATION IN ACTION:

Producing Authentic Historical Interviews

GRADE LEVEL: 8–12

CONTENT AREA/TOPIC: U.S. History

LENGTH OF TIME: Two weeks

Phase 1 Lead from Enduring Problems of Practice

Step 1: Identify problems of practice (POPs)

Like many social studies teachers, Mr. Engle sought to create learning experiences where students could make meaningful connections between the past and present. In past years, students had read accounts of the Holocaust and Rwandan genocides, but he was not sure that his students really understood the experiences of people during these

◀ **Technology Integration in Action** examples located at the beginning of each chapter are school-based scenarios that match the chapter's thematic content. Beginning in Chapter 4 and continuing through Chapter 15, each Technology Integration in Action opening scenario focuses on a teacher's selection and use of specific technology within a classroom environment to solve a specific problem of practice. Each scenario walks the reader through the steps of the Technology Integration Planning (TIP) Model and lesson RATification using the Replacement, Amplification, and Transformation (RAT) Assessment model introduced at the end of Chapter 3. These classroom-based scenarios are tied specifically to the chapter's learning outcomes.

▶ **Digital Equity and Justice** features highlight a digital equity issue relevant to the chapter's thematic content and provide practical suggestions for teachers to take action to examine each issue in locally relevant ways.

BOX 4.1 DIGITAL EQUITY AND JUSTICE

Internet Access

The COVID-19 pandemic blatantly illustrated the breadth of digital inequities in the nation. It is a significant injustice for teachers to assume that all students have access to computers and Internet in their homes and communities. The U.S. Census estimates 82.7% of households have a broadband Internet subscription (U.S. Census, 2019), and Table 4.3 shows a snapshot of Internet availability in 2021 by race and income characteristics. Several trends in the data from the U.S. Census, as shown in the table, are important.

- Some portion (11% or more) of households, across all races, ethnicities, or income levels, do not have Internet *always available*.
- With the exception of census respondents identified as Asian, people of color have less consistent *always available* access to Internet in their households than White respondents.

Table 4.3 Availability of Internet for Educational Purposes in Households with Children in Private or Public Schools (U.S. Census Bureau Household Pulse Survey, Week 24, 2021)

		Always available	Usually available	Sometimes available	Rarely available	Never available
	Total, All (*n* = 50,522,411)	74.8%	17.8%	3.2%	0.9%	0.6%
Race and Ethnicity	Asian alone, not Hispanic	83.9%	12.7%	1.4%	0.1%	0.1%
	White alone, not Hispanic	77.5%	16.5%	2.7%	1.0%	0.3%
	Black alone, not Hispanic	70.6%	16.9%	3.9%	1.0%	2.5%
	Hispanic or Latino (may be of any race)	69.6%	22.2%	3.9%	0.8%	0.3%
	Two or more races + Other races, not Hispanic	67.5%	22.0%	5.9%	1.3%	0.2%
Income	Less than $24,999	64.0%	24.0%	7.2%	2.8%	1.2%
	$25,000–49,999	67.0%	26.6%	4.5%	1.5%	0.2%
	$50,000–99,999	78.2%	18.2%	2.6%	0.5%	0.1%
	$100,000–149,999	83.5%	14.1%	2.1%	0.2%	0.1%
	$150,000 and above	88.2%	8.8%	1.0%	0.7%	1.3%

Table 12.2 Top Ten Must-Have Technologies for STEM Instruction

Technology	Description
Desmos	Desmos is a free online or iPad graphing calculator. Students can save their graphs, equations, tables, and pictures on it. The tool is available in over 20 languages.
EcoLearn	EcoLearn is an educational research group at Harvard that offers a suite of immersive technologies to support learning about the environment (ecoMUVE, ecoMOBILE, ecoXPT, and ecoMOD). These technologies are virtual environments that are appropriate for students in grades 6–12.
GeoGebra	GeoGebra is a dynamic, interactive, online mathematics software package for STEM learning that is appropriate for upper elementary through high school students. It includes a dynamic 2-D and 3-D geometry environment with a spreadsheet, a computer algebra system including statistics and calculus tools, and scripting.
Notability	Notability is an iOS/OSX app that allows students to take multimedia notes and perform PDF annotations. This application is wonderful for notebooking in STEM. Notability enables students to take notes with handwriting by their finger or a stylus, type notes, highlight text, import PDFs and other images, audio-record notes, link audio recordings to written notes, share documents, and sync notes to Dropbox, Google Drive, or Box.
PhET	Free virtual simulations for mathematics and science content. These simulations cross a wide variety of topics and work on many platforms.
Scratch 2/Scratch Jr.	Scratch 2 (web-based) and Scratch Jr. (iPad or Android app) are tools that allow students of all ages to learn to code. It is a block-based computer programming language that allows students to develop and share interactive stories, animations, and games.
Tinkercad	Tinkercad is a free, 3-D modeling computer-aided design software program appropriate for educators and hobbyists. It allows for translation of designs to be actualized through 3-D printing. It is a fun and fairly intuitive program for students to make their design ideas come to life.
TinkerPlots	TinkerPlots is an interactive data visualization and modeling tool for students in upper elementary grades through high school. It is an appropriate tool for any subject in which data need to be analyzed. It allows students to create colorful visual representations that allow for patterns in the data to emerge.
Vernier interfaces and probeware	Vernier interface and probeware sets provide students active hands-on science, engineering, and mathematics learning through a combination of multiple probeware sensors and data loggers for gathering real-time data for experiments and graphical analysis. These are appropriate for students in upper elementary grades through high school.
WISE: Web-based Inquiry Science Environment	WISE is a digital learning platform that allows students to observe, analyze, conduct experiments, and reflect on their learning as they work within WISE projects. Projects are mostly written for middle school students, but a few of them are appropriate for high school. WISE includes the student learning environment as well as many course-management tools and assessments from which teachers can choose.

◄ **Top Ten Must-Have Technologies** identify and describe the most recent and helpful educational technologies in the disciplinary content areas in Chapters 9–15, as selected by the disciplinary expert authors.

Helps Teachers Plan for Effective Technology Integration

► **Technology Integration Examples** (TIEs) in Chapters 2–15 offer numerous technology lesson ideas that reflect the thematic content in each chapter and can inspire lesson planning across the curriculum. Each lesson suggestion is correlated to the ISTE National Educational Technology Standards for Students (2016) and Common Core State Standards, as applicable.

TECHNOLOGY INTEGRATION **Example 2.1**

TITLE: Digital Literacies for Social Justice Inquirers

CONTENT AREA/TOPIC: Literacy

GRADE LEVELS: Middle school

ISTE STANDARDS • S: Standard 1—Empowered Learner; Standard 2—Digital Citizen; Standard 3—Knowledge Constructor; Standard 6—Creative Communicator; Standard 7—Global Collaborator

CCSS: CCSS.ELA-LITERACY.RH.6-8.1, CSS.ELA-LITERACY.RH.6-8.4, CCSS.ELA-LITERACY.RH.6-8.8

DESCRIPTION: Students can become a community of social justice inquirers who seek to learn about local issues and advocate for social change. These New York City students began by identifying important topics and chose to investigate their community's poverty and crime. Students brainstormed their own knowledge and their questions about the topic using Answer Garden, a collaborative brainstorming tool. They watched a film documentary that revealed the social construction of class in their neighborhood and other wealthier neighborhoods, after which they explored and observed their neighborhoods, capturing and sharing digital photographs and notes within a collaborative Google Doc. They used curated information on Flipboard to further develop their background knowledge. Then, students began expressing their developing knowledge as counter-stories about race, class, and crime by creating memes using Meme Generator. In class discussions, they culminated the unit by generating ideas for solution-oriented actions they might take in their community.

SOURCE: Based on Price-Dennis, D., & Carrion, S. (2017). Leveraging digital literacies for equity and social justice. *Language Arts*, *94*(3), 190–195.

CHAPTER 6 SUMMARY

The following is a summary of the main points covered in this chapter.

1. **Design, Analysis, and Creation**
   - Teachers and students engage in design and transmediation processes when using digital resources to express their ideas, concepts, or knowledge.
2. **Digital Writing and Publishing**
   - Digital writing and publishing activities can be accomplished with word processing and desktop publishing software.
   - Written and artistic expressions can be published online or created in digital stories or books. Integration ideas include content-related creations, such as cookbooks, field guides, or creative writing.
3. **Creating Multimodal Representations**
   - Digital representations help teachers and students display information, including text, images, graphics, symbols, audio, video, and websites to demonstrate concepts or developed knowledge.
   - Teachers use representations to enhance the impact of spoken information, enable multimedia-rich content depictions, make content polished and professional, organize thinking about a topic, and create enduring learning artifacts. Uses include demonstrating content concepts, illustrating problems and solutions, presenting informational summaries, using multimedia assessment, creating tutorials or game-based reviews, and developing interactive lessons.

◄ **Summaries** at the end of each chapter tie back to the learning outcomes and act as study aids by condensing and reviewing critical chapter content.

Helps Teachers Practice Technology Integration

Teacher Growth in Technology Integration Strategies for Music

These sections have introduced the issues, challenges, and strategies for integrating technology into music instruction and learning. In the future, teachers can begin developing expanded and strengthened capabilities to understand emerging issues, generate possible solutions, and address technology integration in music education. Review the rubric in Table 14.3, which can guide a teacher's progress in integrating technology in music instruction.

In the mid-2010s, the National Coalition for Core Arts Standards released updated standards for dance, media arts, music, theater, and visual arts. These standards are shaped around fundamental processes of interacting with the arts: creating, performing/presenting/producing, responding, and connecting. The standards in music vary in their usefulness, but it is important to note that, in the 2014 version of the music standards, there is a strand of music technology standards. Music teachers wishing to integrate technology into their teaching may look to this set of standards for high-level guidance.

In addition to resources from this chapter, teachers can become involved in music professional organizations, such as NAfME and TI:ME, both of which offer teaching resources, advocacy ideas, professional development, and collaboration opportunities. The American Mathematical Society is another organization that offers specific resources for connecting mathematics and music. Finally, teachers

◀ **A Teacher Growth Section** located at the end of each discipline-specific chapter (Chapters 9–15) offers strategies for continued teacher learning and leadership in content-specific technology integration. It also includes a rubric that teachers can use to self-assess and direct their growth in technology integration and suggests Twitter hashtags to follow.

▶ **A Technology Integration Workshop** located at the end of every chapter includes hands-on, interactive activities that connect chapter content to real-life practice. Each contains the following:

TECHNOLOGY INTEGRATION WORKSHOP

Apply What You Learned

In this chapter, you learned about teaching and learning with technology in health and PE. Now apply your understanding of these concepts by doing the following activities:

- Reread Mr. Martinez's lesson *Developing an Interest-Based, Personal Physical Activity Plan* at the beginning of this chapter. Pay close attention to Step 3 of the Technology Integration Planning (TIP) model when they identify the technological possibilities for their problem of practice: increasing students' physical activity, optimizing healthy eating, and engaging in the scientific method. Using your knowledge about technology integration strategies for health and PE introduced in this chapter, generate at least one new technological possibility for targeting Mr. Martinez and Ms. Floyd's problem of practice.
- Review how Mr. Martinez and Ms. Floyd RATified the lesson in Step 5 of the TIP model, as represented in Table 15.1. Use the **RAT Matrix** to analyze the role(s) and relative advantage that your new technological possibilities (identified in the preceding step) would play in the lesson. You must reflect on the

- **Apply What You Learned** exercises, which call for students to reread the Technology Integration in Action example that opened the chapter; identify another, different technology resource possibility to solve the problem of practice set within the example; and complete a RAT matrix analysis to determine the new technology resource's potential for changing instruction, learning, and/or curriculum.
- **Technology Integration Lesson Planning: Evaluating Lesson Plans** exercises provide students the opportunity and resources to evaluate a set of technology integration lessons.
- **Technology Integration Lesson Planning: Creating Lesson Plans with the TIP model** activity asks students to create a new technology-supported lesson plan that employs a technology resource introduced in the chapter to solve a problem of practice. Students do so by implementing the TIP model and are encouraged to share their lessons.
- **Technology Lesson Plan Evaluation Checklist and the RAT matrix** introduced in Chapter 3 are used throughout the workshop activities.

Learning Management System (LMS)–Compatible Assessment Bank, and Other Instructor Resources

LMS-Compatible Assessment Bank

With this new edition, all assessment types—quizzes, application exercises, and chapter tests— are included in LMS-compatible banks for the following learning management systems: Blackboard (**9780137544455**), Canvas (**9780137544486**), D2L (**9780137544523**), and Moodle (**9780137544530**). These packaged files allow maximum flexibility to instructors when it comes to importing, assigning, and grading. Assessment types include:

- **Learning Outcome Quizzes** Each chapter learning outcome is the focus of a *Learning Outcome Quiz* that is available for instructors to assign through their LMS. Learning outcomes identify chapter content that is most important for learners and serve as the organizational framework for each chapter.

The higher-order, multiple-choice questions in each quiz will measure your understanding of chapter content, guide the expectations for your learning, and inform the accountability and the applications of your new knowledge. Each multiple-choice question includes feedback for the correct answer and for each distractor to help guide students' learning.

- **Application Exercises** Each chapter provides opportunities to apply what you have learned through *Application Exercises*. These exercises are usually short-answer format and are based on the Technology Integration in Action opening scenarios at the beginning of Chapters 4–15. The exercises draw students to consider how the teacher in the opening scenario engages with the Technology Integration Planning model to design a technology-integrated lesson. Students engage with the TIP steps to identify the problem of practice, technology possibilities, integration strategy, technology-related assets, and the RATification (relative advantage) within the lesson. After deep analysis of that lesson, students are called upon to use the broader content from the chapter to propose alternative technological possibilities to solve the problem of practice and how they would RATify the lesson. Finally, students will use resources from the text to evaluate other lesson plans related to the content of the chapter to determine if they would or would not use them through the RATification process to determine relative advantage. A model response written by experts is provided to help guide learning.
- **Chapter Tests** Suggested test items are provided for each chapter and include questions in multiple-choice and short-answer/essay formats.

Instructor's Manual (9780137544431)

The Instructor's Manual is provided as a Word document and includes resources to assist professors in planning their course. These resources consist of chapter overview concepts to emphasize, chapter activities, group activities, and assessment activities.

PowerPoint® Slides (9780137544554)

PowerPoint slides are provided for each chapter and highlight key concepts and summarize the content of the text to make it more meaningful for students.
Note: All instructor resources—LMS-compatible assessment bank, instructor's manual, and PowerPoint slides—are available for download at www.pearsonhighered.com. Use one of the following methods:

- From the main page, use the search function to look up the lead author (i.e., Hughes), or the title (i.e., Integrating Educational Technology into Teaching: Transforming Learning Across Disciplines). Select the desired search result, then access the "Resources" tab to view and download all available resources.
- From the main page, use the search function to look up the ISBN (provided above) of the specific instructor resource you would like to download. When the product page loads, access the "Downloadable Resources" tab.

Acknowledgments

Both the goal and challenge of this book have been to provide the reader with the most up-to-date foundations, theory, research, and practices in educational technology across the disciplines. We believe this goal has been achieved. As in any project, realizing this goal would not have been possible without the assistance of numerous individuals who helped sharpen the focus of this edition. These individuals include the reviewers for

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The vibrancy of this new edition is partly due to the contributors for the current edition, who all engage in researching and using the latest technology-supported teaching and learning approaches in their discipline areas. The contributors include the following:

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From MDR: In this, the last edition of this textbook to reflect my name as author, I acknowledge ineffable gratitude to retired Pearson editor Debbie Stollenwerk, who first saw the book's potential for transforming perceptions about technology's uses in education and took a chance on a virtually unknown author; and to my family, Bill and Paige Wiencke, whose support enabled me to create the first edition published in 1996, all subsequent ones, and indeed, everything I have been able to accomplish throughout my professional career. I would also like to continue to remember and acknowledge the influences of family who are with us now only in memory: our parents Servatius Lee Roblyer and Phrona Catherine Roblyer and Raymond and Marjorie Wiencke. Finally, my thanks go to Joan Hughes who took over work on this text so it might continue its usefulness in classrooms around the world.

From both authors: We would like to acknowledge all the educators whose perseverance and commitment to their students remains a constant we can count on, especially during the recent COVID-19 pandemic.

—Joan E. Hughes and M. D. Roblyer

Breif Contents

Contents

PART 1 Technology Integration and Leadership in Education

PART 2 Digital Content for Learning

PART 3 Digital Resources for Critical Thinking, Creating, Communicating, and Collaborating in Blended and Online Contexts

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CHAPTER 1

Educational Technology in Context

THE BIG PICTURE

Learning Outcomes

After reading this chapter and completing the learning activities, you should be able to:

1.1 Analyze how (a) the definition for educational technology and integrating educational technology and (b) the history of digital technology shapes opportunities for integrating educational technology in classrooms. (ISTE Standards for Educators: 1—Learner; 5—Designer)

1.2 Characterize trends in established and emerging technologies and describe how they shape educational innovations. (ISTE Standards for Educators: 1—Learner; 2—Leader; 5—Designer)

1.3 Articulate the impact of leadership, politics and policies, infrastructure, safety, and equity and social justice conditions on current uses of technology in education. (ISTE Standards for Educators: 2—Leader; 3—Citizen; 4—Collaborator; 5—Designer)

TECHNOLOGY INTEGRATION IN ACTION:

Then and Now

Then . . . Ms. Thomas was almost as proud of her new classroom computers as she was of her new teaching degree. She had high hopes for the 1985 school year in her first teaching position, especially because the principal had asked her whether she could use two brand-new Apple computer systems that had been donated to the school.

Ms. Thomas also found MECC software, such as Oregon Trail, and successfully lobbied the principal to buy it. With Oregon Trail, students were transported to 1848 as pioneers traveling from Missouri via wagons to resettle in Oregon. She also discovered Apple **Logo**, with which students could engage in computer programming that controlled a turtle icon that moved and drew lines on the screen. All the students wanted to use the computers, but with only two machines, Ms. Thomas quickly managed the activities to allow everyone to have turns. By the end of the year, she was convinced that these computers led her students to experience learning in different ways, such as through simulated historical experiences or building logic and control with Logo. She expected computers to become an integral part of everyday teaching activities, and she planned to be ready for the future.

(*Continued*)

Now . . . As Ms. Thomas begins another school year, she reflects on her first pioneering work with her Apple computers more than 35 years ago and the technology possibilities available now. She has an **interactive whiteboard**, a device that allows her to project information from a computer to a screen and then manipulate it either with special pens or hands. Ms. Thomas and all her students use tablet computers as part of the school district's **one-to-one computing** initiative for student-centered, hands-on learning. With these devices, her students access science simulations and online math manipulatives, engage in **makerspace** projects, and participate in **citizen science** with others around the state to gather and compare data on local environmental conditions. Students use **graphing calculators** to solve problems, use online programs to learn foreign languages, and take **virtual field trips** in science and social studies. A video project to interview war veterans has drawn a lot of local attention, and the student projects displayed on school digital displays are ablaze with websites and images students had taken with digital cameras.

Ms. Thomas and her teacher colleagues also communicate via email or online chats, and many use a school-approved **learning management system (LMS)** for learning—Google Classroom or Schoology—so that students and parents can get up-to-date information on school and classroom activities and communicate with each other and the teacher. The LMS and the tablets were crucial to continue learning during emergency situations, such as the pandemic, forest fires, and hurricanes.

There were still problems, of course. Computer **viruses** and **spam** sometimes slowed the district's network, and the **firewall** that had been put in place to prevent students from accessing undesirable websites also prevented access to many other perfectly good sites. Teachers reported intermittent problems with **cyberbullying** and inappropriate postings on social network sites despite the school's **acceptable use policies**. Some teachers complained that they had no time for innovative technology-based projects because they were too busy preparing students for the state tests that would determine students' progress, their school's rating, and their own effectiveness scores as teachers.

Despite these concerns, Ms. Thomas is amazed at how far educational technology has come from those first, exciting, exploratory steps she took back in 1985 and how much more there still is to examine. She knows other teachers her age who retired, but she's too interested in what she's doing to retire yet. She's helping with an online program for homebound students and leading a professional development project to support other teachers in using technologies that positions all learners as empowered and agentic. Ms. Thomas is looking forward to the future.

Introduction

Today's educators may think of educational technology as devices or equipment—such as computers, mobile phones, and tablets. But educational technology is not new at all, and it is by no means limited to a list of technical devices or software. Contemporary tools and techniques are simply the latest innovations in a field that is as old as education itself. This chapter introduces our definition of educational technology and the historical perspectives that have contributed to it, the emerging trends that may inspire you, and the conditions that influence the role these innovations may play in the schools you work in today or in the future. In this chapter, you will learn by doing the following:

- **Reviewing key terminology.** Talking about a topic requires knowing the vocabulary and concepts relevant to that topic. We break down the idea of "educational technology" as a resource and a process educators implement in practice.
- **Reflecting on the past.** Showing where the field began helps us understand where it is headed and why. Over time, changes in goals and methods in the field cast new light on the challenges and opportunities of today's technologies.
- **Looking ahead to the future.** Technology resources and societal conditions change so rapidly that today's teachers must be futurists who critically analyze emerging trends.
- **Considering the conditions.** Available technologies may provide possibilities, but a combination of leadership, political, infrastructural, safety, equitable and socially just issues influence the current uses of educational technology.

This text provides you a guided journey through the process of integrating educational technology, as defined in the next section. This chapter provides the big picture, including key definitions, concepts, and processes involved in integrating educational technology. That process is broken down further in Chapters 2 and 3 where we outline the three parts of our definition of integrating educational technology. Chapter 2 introduces the importance of learning theories, pedagogy, and curriculum. Chapter 3 introduces the roles for technology tools, support, and expertise, culminating with the Technology Integration Planning (TIP) model that teachers use to design technology-integrated lessons for their own classrooms. The TIP model is demonstrated in a *Technology Integration in Action* scenario that begins all subsequent chapters and is the focus of the workshop activities that close each chapter. Chapters 4–7 provide in-depth reviews of digital content resources for learning, communicating, designing, analyzing, creating, and making. Chapter 8 culminates with guidance in using all the resources and planning guides introduced in Chapters 1–7 to build out blended and online learning experiences. The latter half of the book, Chapters 9–15, provide key issues and technology integration strategies for content areas, including special education; English and language arts; English as an additional language and foreign languages; science, engineering, and mathematics; social studies; music and art; and physical and health education. All the technology integration strategies are grounded in strong educational research.

The "Big Picture" of Educational Technology

Learning Outcome 1.1 Analyze how (a) the definition for educational technology and integrating educational technology and (b) the history of digital technology shapes opportunities for integrating educational technology in classrooms. (ISTE Standards for Educators: 1—Learner; 5—Designer)

The big-picture review in this section introduces a definition of the term *educational technology* that is built on decades of work in this field. Saettler (1990) says that the earliest references to educational technology were made by radio instruction pioneer W. W. Charters in 1948. Across the last seven decades, unique outlooks on what technology in education is and should be have emerged from different professional organizations, but definitions commonly encompass both technological resources and educational processes. We refer to *education technology* as the ethical and just practice of leveraging technology *resources* to support the educational *processes* involved in teaching and learning. Educational technology is an active, engaged practice; it is not a singular technology tool. It has been built on decades of research and development.

How This Textbook Defines Educational Technology

In this section, we introduce the fundamental processes and resources that contribute to an informed practice of educational technology.

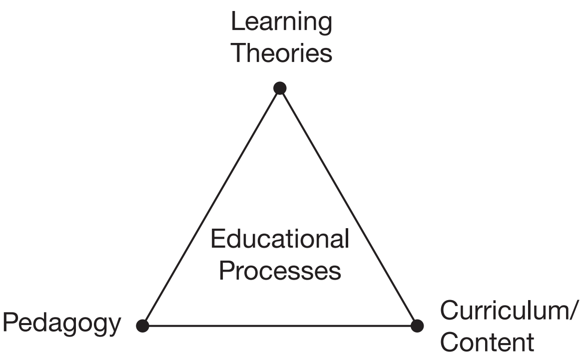
- **Educational technology** refers to the ethical and just practice of leveraging *resources* to support the educational *processes* involved in teaching and learning.
- **Educational processes** include a set of three knowledge areas through which to consider the role of technological resources, including (1) learning theories based on the sciences of human cognition, (2) pedagogical or instructional practices that complement learning theories, and (3) curriculum standards or content knowledge that inform our learning objectives or goals. Chapter 2 reviews these educational processes in depth.
- **Technology resources** in this textbook are viewed as technology tools and technology support and expertise. We choose the term **resource** to capture the supply of both technological tools and human technological support or expertise that exists within people or in resources (e.g., a website or online community) built by knowledgeable others. A technology **tool** is a device such as a **clicker** or software application

such as a word processor or Twitter that accomplishes a specific task. Technological support and expertise exist among school personnel. For example, librarians, media specialists, and other teachers in your school might provide ideas and expertise for using technologies in lessons. Principals might provide special funding for projects you develop. Chapter 3 introduces these resources and describes how teachers can build a community of support for developing and accessing technological expertise. Chapters 4–7 provide even more coverage of available technology tools.

- **Integrating educational technology** refers to an individual or collaborative process of (1) identifying **problems of practice (POPs)** (e.g., learners' needs or misconceptions, lack of culturally relevant curricular materials, difficult teaching topics), (2) accessing technological resources as possible solutions, (3) leveraging the resources in your learning context, and (4) assessing whether the educational technology solves the target POP in ways that replace, amplify, or transform teaching and learning. Chapter 3 introduces the **Technology Integration Planning (TIP)** model to help guide teachers through the process of integrating educational technology.

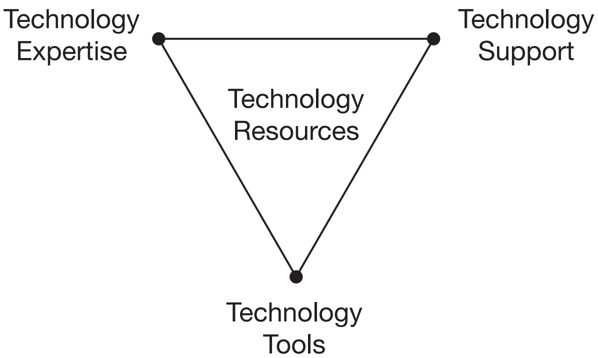
Figure 1.1 visualizes the processes and resources in a framework for integrating educational technology.

Figure 1.1 A Framework for Integrating Educational Technology



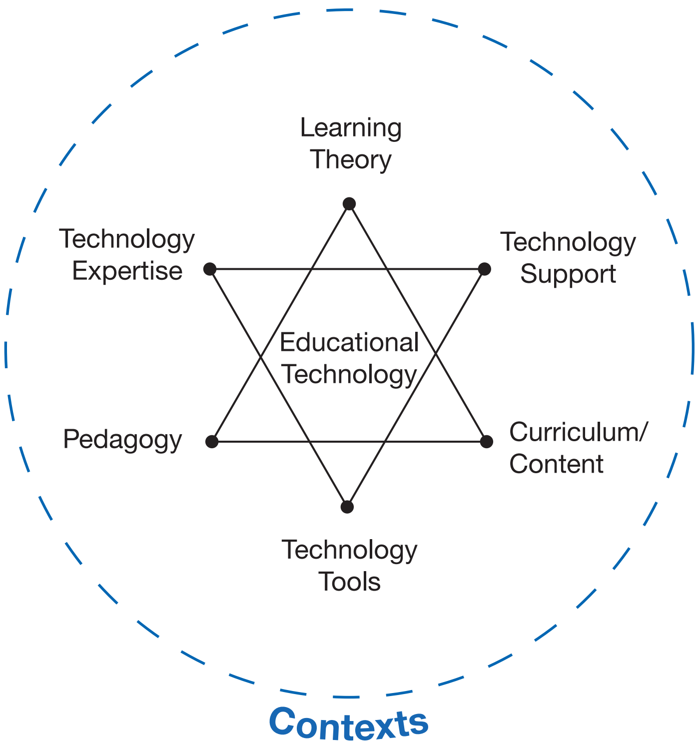
(a) Identify problems of practice.

Identify problems of practice (POPs; e.g., learners' needs or misconceptions, lack of culturally relevant curricular materials, or difficult teaching topics) by consulting the educational processes with which teachers engage every day.



(b) Identify technology possibilities.

Identify possible technological solutions for your POPs by reviewing the technology resources available at your school.



(c) Use and assess educational technology.

Once you choose a technology resource to tackle the target POP in ethical ways that are equitable and empowering for students, you are enacting educational technology. Once you've harnessed educational technology for teaching or learning, you will want to assess its effectiveness in solving the target POP.

Educational Technology Across Time

Our current approaches to integrating educational technology into classrooms have been shaped by decades of developments in digital technologies. The six eras in the history of digital technologies, shown in Figure 1.2, are described in this section.

Figure 1.2 Digital Technologies in Education: A Timeline of Events That Shaped the Field

Mainframe Computer Era

- **1950 First computers are used for instruction** Computer-driven flight simulator trains MIT pilots
- **1959 First computer is used with school children** IBM 650 teaches binary arithmetic in New York City
- **1960s University time-sharing movement begins** Mainframes used for programming and shared utilities
- **Early 1970s Computer-assisted instruction (CAI) movement begins** Schools use university-based mainframes/mini-computers
- **Mid-to-late 1970s Schools begin using computers for instruction and administration** CDC announces PLATO system

Computer Era

- **1967 Logo programming language developed** Seymour Papert is part of team to produce first version of Logo
- **Late 1970s Arthur Luehrmann coins term *computer literacy*** Andrew Molnar warns: non-computer-literate students are a risk
- **1977 Computers enter schools** Teachers begin to control instructional applications
- **1980s Computer movements begin** Software publishing, teacher authoring, LOGO problem solving get underway
- **1980s-early 1990s Networking computers begin** ILS marks a shift to networks and away from desktop computers

Internet Era

- **1993 World Wide Web is born** First browser (Mosaic) transforms Internet, and teachers enter information superhighway
- **1994 Internet use explodes** Distance learning increases in higher education
- **1995 Virtual schooling begins** Online courses begin being offered in high schools
- **1998 Google is founded** Google will grow to dominate the search engine market
- **1999 Wi-Fi standards are developed** Schools begin to install Wi-Fi to connect to the Internet

Mobile Technologies, Social Media, and Open Access Era

- **2001 Wikipedia begins** Crowdsourcing movement gains momentum
- **2005–06 Social networking begins** Facebook and Twitter are invented
- **2007 Books go digital and mobile** Amazon releases first Kindle e-book reader
- **2010 Mobile tablets become available** Apple releases first iPad tablet computer
- **2016 MIT celebrates 15th anniversary of their opencourseware initiative** MIT has more than 2,200 courses available free of charge to support knowledge sharing

Personalized, Adaptive Learning Era

- **2008 Adaptive learning engine emerges** Knewton adaptive learning platform founded
- **2009 USDOE emphasizes data systems** "Race to the Top" program funded systemic change involving data innovations to support student growth and instruction
- **2014 "Breakthrough" schools funded** Next Generation Learning Challenges (NGLC) allocates $7.2 million toward personalized, competency-based schools
- **2016 Facebook's Zuckerberg joins education efforts** Chan Zuckerberg Education Initiative build personalized learning technologies, Summit Learning
- **2019 Skepticism about personalized adaptive learning grow** Knewton is sold (at a loss) to Wiley Publishers & Summit Learning's platform and curriculum critiqued

Digital Justice Era

- **2019 Federal Government focuses on ed tech equity** NCES identify data collection priorities on technology resources and support, integration of technology, and tech knowledge, skills, and attitudes
- **2020 Pandemic emergency remote teaching (ERT) reveals enduring inequities** Children and parents have no or inadequate internet, devices, and low digital literacy skills
- **2020 Online Proctoring Software Raises Equity Issues** Some argue these systems have discriminatory consequences or privacy issues
- **2020 COVID Relief Bill 2020 Opens Doors for Digital Equity** Funds were allotted for households' emergency internet service, tribal connectivity, and broadband expansion in underserved communities
- **2021 Infrastructure Act and Digital Equity Act signed into law** $65 billion provided for broadband expansion and digital equity and inclusion programs

MAINFRAME COMPUTER ERA In the 1950s–1970s, companies like IBM developed instructional **mainframes**, or large-scale computers that were often the size of a room. Researchers used these systems to develop CAI materials that schools used via long-distance connections to the mainframe. CAI was instructional software designed to help teach information and/or skills related to a topic. Companies such as the Computer Curriculum Corporation (CCC) and the Programmed Logic for Automatic Teaching Operations (PLATO) system (developed by Control Data Corporation) dominated the field for about 15 years.

COMPUTER ERA In contrast to mainframes, in the late 1970s and 1980s, small, stand-alone desktop **computers**, designed for use by only one person at a time, became available. School districts placed them directly into the hands of teachers and schools. An educational software publishing movement quickly sprang up to provide teachers and students software to use on computers. Researchers realized both teachers and students required skills in using the computer, and researcher Arthur Luehrmann coined the term **computer literacy**. MIT researcher Seymour Papert contributed to developing **Logo**, a programming language, and used it as an aid to teach problem solving. Networked **integrated learning systems (ILSs)**, which provided computer-based instruction and summary reports of student progress, also were developed to help teachers address required standards.

INTERNET ERA The **World Wide Web (WWW)**, now simply known as the **web**, was invented in the 1990s. This was a system within the **Internet** that allowed graphic displays of websites through hypertext links, pieces of texts or images that allowed users to jump to other locations connected by the links. Teachers and students used **browser** software to explore information on the web, and by the beginning of the 2000s, email, web-based multimedia, and videoconferencing became standard tools of web users. Websites became a primary form of communication for educators, and web-based distance education became a more prominent part of instructional delivery at all levels of education. The meaning of "online" changed from simply being on the computer to being connected to the web. **Virtual schools**, which facilitate learning when K–12 students and teachers are physically separated and instruction is synchronous or asynchronous, began a steady growth that has endured in public, charter, and private education.

THE MOBILE TECHNOLOGIES, SOCIAL MEDIA, AND OPEN ACCESS ERA In the early 2000s, portable devices such as smartphones and tablets made web access and computer power more ubiquitous. More and more individuals made texting and social networking sites, such as Facebook, Twitter, and Instagram, part of their everyday lives. The ease of access to online resources and communications drove several movements.

- **Distance learning.** A dramatic increase in the number and type of distance learning offerings came about first in higher education and then in K–12 schools.
- **Electronic books** (**e-books** or **e-texts**). Texts in digital form on computers, e-book readers, and smartphones became increasingly popular alternatives to printed texts.
- **Open access.** Initiatives began to gather learning materials and make them available "**open**" online, which means that anyone can access them for free and modify, remix, and reuse the content with appropriate attribution and without fees for others' use. **OpenCourseWare (OCW)** and open-access university offerings called **Massive Open Online Courses (MOOCs)** became available.
- **Mobile access.** One-to-one laptop programs (and later tablet programs) as well as **Bring Your Own Device (BYOD) programs** allowed students to use their own handheld devices for learning activities and accelerated the move to bring computer and Internet access into all classrooms.

As ubiquitous communications and social networking defined social practices in modern life, educators struggled to create appropriate policies and uses that could take advantage of this new power while minimizing its risks and problems.

THE PERSONALIZED, ADAPTIVE LEARNING ERA Innovators began building personalized, adaptive learning software that is similar to, yet more powerful than, the CAI and ILS systems of the mainframe and computer eras. By recording every click of a mouse, this adaptive learning software can adjust to learners' needs through sophisticated analysis of learner behaviors and interactions with resources or content. This software adapts immediately by changing content, activities, and assessments to create a personalized learning path for each student. Most textbook publishers and app developers are building adaptive technology into their new products. For example, Dreambox Learning is adaptive math software with game-based elements. In many cases, a data dashboard is available for the teacher and school leaders and sometimes for the learner and parent. Teachers can use the dashboard to examine individual student progress and provide further interventions as needed. School leaders can use dashboards to discover patterns in students' learning needs. However, some controversy has emerged about these innovations, such as parents and students expressing dissatisfaction with Summit Learning personalized platform and curriculum in their districts (Bowles, 2019).

THE DIGITAL JUSTICE ERA With growing educational commitments to social justice, the work of many researchers and practitioners to identify more equitable, inclusive, and antiracist or anti-oppressive educational technology is becoming an imperative. This work raises critical questions regarding the content and functionality of software and hardware; the access to digital connectivity and resources; and the ways resources are used by teachers, students, and parents. For example, some worry that the vast data collected about learners might be harmful (Shulman, 2016), and concerns have arisen regarding ownership, control, access, use, security, and privacy of the data.

BOX 1.1 DIGITAL EQUITY AND JUSTICE

Definitions and Goals

As a nation, we have not yet achieved **digital equity**, which is "a condition in which all individuals and communities have the information technology capacity needed for full participation in our society, democracy and economy. Digital Equity is necessary for civic and cultural participation, employment, lifelong learning, and access to essential services" (National Digital Inclusion Alliance, n.d.). Visit the U.S. Census' latest American Community Survey to explore your state's digital equity gap in terms of the percentage of households (1) lacking wired home broadband connections, (2) having no home Internet of any kind, and (3) having an Internet subscription by income level (e.g., below $20,000 and above $50,000/year).

As educators, we must work toward achieving digital equity, through **digital inclusion**, which are activities we can do to ensure all individuals and communities, especially groups that have been identified as having endured **digital inequities**, have access to and use technology. Five important elements of inclusion are:

1. Affordable, robust broadband Internet service
2. Internet-enabled devices
3. Digital literacy training
4. Technical support
5. Applications and online content that enable self-sufficiency, participation, and collaboration (**National Digital Inclusion Alliance, n.d.**).

In terms of schools and children, educators must constantly monitor the degree to which all children have access to Internet-ready device(s), high-speed Internet, and just-in-time technical support so they can develop applicable digital literacy competencies and use apps and digital content that privilege high-quality learning experiences that involve participation, collaboration, and student agency in the activities. These elements of digital inclusion have been argued to be a human right (Cancro, 2016), a civil rights issue (Krueger & James, 2017), and instrumental for societal progress (Gonzales, 2016). Thus, as an expression of social justice, our nation's schools and educators must actively seek **digital justice** wherein we identify and eliminate historical, institutional, and structural barriers to access and use technology for learning in classrooms, schools, homes, and communities.

National and state emergencies that closed schools brought attention to enduring digital inequities, such as lack of access to high-speed Internet, digital devices, and software for online learning within children's homes and communities. Others question if software is anti-oppressive and supports humanizing pedagogy, such as considering software that compels teachers to rate students' behaviors or online test proctoring that introduces surveillance into learners' homes as forms of oppression.

How What We Have Learned from the Past Shapes our Future

To help us become more equitable and effective technology users today, we can apply what we know about the past to future decisions and actions. Developments in digital technologies along with societal changes have shaped the history of educational technology. The following points are among the most important.

No technology is a panacea for education. Great expectations for products such as Logo, online MOOCs, and adaptive technologies have taught us that even the most current, capable technology resources offer no quick, easy, universal, or equitable solutions. Computer-based materials and strategies are usually tools in a larger system and must be integrated carefully with other resources and teacher activities. Planning to integrate educational technology must always begin with the question, What specific needs do my students and I have that (any given resource) can help meet?

Teachers usually do not develop technology materials or curriculum. Teaching is one of the most time- and labor-intensive jobs in our society. With so many demands on their time, most teachers do not develop software or create complex technology-based teaching materials. Publishers, software companies, school or district developers, researchers, and most recently, philanthropic organizations have provided the majority of this assistance. Yet, teachers have the important responsibility to vet these materials for appropriateness and equity.

"Technically possible" does not equal "desirable, feasible, or inevitable." Technology can bring undesirable—as well as desirable—changes. For example, increased access to cell phones and tablets in classrooms means that online communication and information are increasingly available. But communication always comes with caveats, and readily available information is not always reliable or helpful. New technological horizons require teachers to analyze carefully the implications of each implementation decision. Better technology demands that we become critical consumers of its power, capability, and inequity. We are responsible for deciding just which educational technology becomes reality in our classrooms.

Technologies change faster than teachers can keep up. The history of educational technology has shown that resources and accepted methods of applying them will change, often quickly and dramatically. The need to continue learning new resources and to change instructional methods places a special burden on already overworked teachers. Educators might not be able to predict the future of educational technology, but they know that it will be different than it is in the present; that is, they must anticipate and accept the inevitability of change and the need for continual learning.

Many technologies do not change educational practices. Technology in education is an area especially susceptible to fads. The past has shown that teachers must be careful, analytical consumers of technological innovation, looking to what has worked in the past to guide their decisions and measure their expectations in the present. Educational practice tends to move in cycles, and "new" digital methods are often old methods in new guise. In short, teachers must be as informed and analytical to ensure new digital resources offer advantages over current instructional practices.

Teachers will always be more important than technology. The developers of the first instructional computer systems in the 1960s foresaw them replacing many teacher positions; some advocates of today's online learning methods and personalized learning systems envision a similar impact on future education. Yet good teachers are more essential now than ever. We need more teachers who understand the role that technology plays in society and in education, who are prepared to take advantage of its power, and who recognize its limitations. In an increasingly technological society, we need more teachers who are technology savvy, critically aware, and child centered.

Established and Emerging Educational Technology Trends

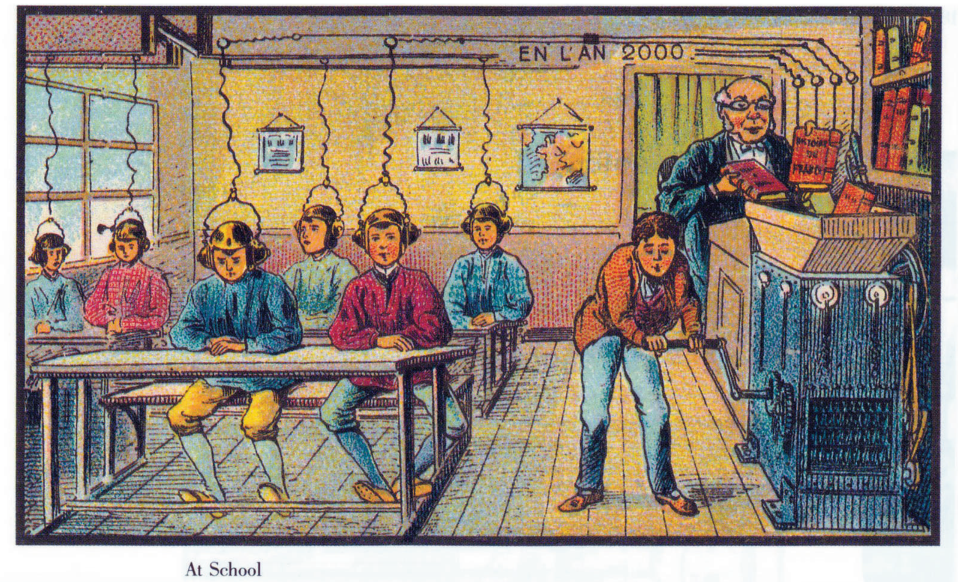
Learning Outcome 1.2 Characterize trends in established and emerging technologies and describe how they shape educational innovations. (ISTE Standards for Educators: 1—Learner; 2—Leader; 5—Designer)

Visions of the future are suffused with images of technologies that may seem magical and far-fetched. Figure 1.3 is most likely attributed to French artist Jean-Marc Côté, who envisioned that a century later, in the year 2000, a technology could grind books' content and insert information and knowledge directly into students' heads. While this invention has never come to be, we know that future education may have access to innovations that leverage current technical inventions. Educators must identify how to take advantage of their capabilities to bring about the future education systems that advance a democratic society.

Figure 1.3 A postcard from circa 1901 depicting how French artist Jean-Marc Côté envisioned education a century later in the year 2000. The image connotes a teacher who pushes content information from books through a machine that transports the information into students' heads via wired ear/head caps while they sit passively at tables in rows in a classroom.

Public Domain:

https://commons.wikimedia.org/wiki/Category:France_in_XXI_Century_(fiction)#/media/File:France_in_XXI_Century._School.jpg



Trends in Hardware and Software Innovation

Hardware and software developers are capitalizing on ever-expanding computing power and high-speed Internet to create a range of innovations applicable for schools. Since schools have widely varied infrastructure, the following trends reflect technical innovations that are nearly established as well others that more emergent in K–12 educational systems.

TREND 1: MOBILE COMPUTING The trend toward mobile devices in education is already widespread and having a great impact on K–12 education. The portability of tablet devices facilitates instant off/on, ubiquitous Internet access, rapid communication, and access to digital content. Thriving app development for tablets is driving this trend and increasing the options they enable. Cloud-based storage and communications also enable this trend. Some schools allow students who already own personal technology devices to use them in classes, creating a BYOD environment. Then these schools invest in mobile devices only for students who don't have them. Concerns about curriculum, privacy, classroom management, and equitable access abound. In the Coachella Valley Unified School District in California, many students live in rural sections of the district where the local cable company would not install fiber optic cables to support Internet access. The district outfitted their school buses with solar-powered Wi-Fi and parked many of the buses overnight near the Internet-poor zones to maximize students' use of mobile technologies. During the COVID-19 pandemic, districts across the United States implemented Wi-Fi buses to increase Internet access.

TREND 2: DIGITAL AND OPEN CONTENT Although digital resources have been available for decades, their technical sophistication continually improves and teachers can consider them more often, especially when students have access to mobile devices. Publishers of textbooks are quickly generating digital-content options for schools, and libraries are purchasing access to more e-books. **Open educational resources (OER)** are materials created to be shared, adapted, and used by others without fees but with required attribution to the creator of the materials. Some open content is created as small modular formats that allow flexible incorporation into learning experiences; there are also open textbooks with a full curriculum. This trend also means the availability of more free content that can be adapted for K–12 teachers and students. The student in the accompanying photograph is reading an e-book on her tablet.


E-book reading via mobile device

TREND 3: LEARNING MANAGEMENT SYSTEMS **Learning management systems (LMSs)** have been in use for decades in higher education and are now becoming more ubiquitous within K–12 schools. LMSs, such as Google Classroom, Blackboard, Canvas, Schoology, and Seesaw, are online "classrooms" that live on the web for students. Teachers can use tools within these systems, such as digital file storage, quizzes, discussion forums, wikis, and collaborative documents, to build modules of instruction or supplementary materials for their classes.

TREND 4: ARTIFICIAL INTELLIGENCE AND LEARNING ANALYTICS With more learners using a myriad of online or digital learning resources, every click of a mouse can be recorded and stored. This amassed data is referred to as **big data** because it can be immense. Innovators are building new instructional and administrative platforms that use **machine learning**, a type of artificial intelligence, to analyze big data and predict the content and instruction needed to support learners' progress. This process is called **learning analytics**, or the ability to detect trends and patterns from sets of performance data across large numbers of students. The goal is to find ways to apply findings across students to create a personalized approach to learning for each student.

TREND 5: ROBOTICS AND CODING Affordable hardware, such as Arduinos, Raspberry Pi, and some 3-D scanners, have enabled more schools to adopt a robotic engineering curriculum to support learning in science, technology, engineering, and mathematics (STEM) for K–12 students as an after-school extracurricular activity or as part of a STEM discipline. Students engage in a range of activities from **computer programming**, using robot controllers, switches, sensors, motors, and LEGO kits to design, build, and program robots—often for competitions. For Inspiration and Recognition of Science & Technology (FIRST) is a nonprofit organization that offers LEGO-based robotics programs and competitions for children ages 6–14 who research real-world scientific problems and offer prototypes of innovative solutions. NASA also supports robotics education through the Robotics Alliance Project. It provides a list of curriculum, competitions, and internships appropriate to K–5, 6–8, and 9–12 grade levels and higher education.

TREND 6: AUGMENTED, VIRTUAL, AND MIXED REALITY **Augmented reality (AR)** refers to a combined hardware and software platform that creates a computer-generated environment in which a real-life scene is overlaid with information that enhances our uses of it. In **virtual reality (VR)**, a person wears a headset and sometimes a data glove through which they are immersed into and can interact with a computer-generated 3-D, lifelike simulated environment. **Mixed reality** combines both AR and VR systems to interact in a person's real world. Versions of these systems are available to schools on mobile devices.

Educational Trends Leveraging Technology Innovations

Educators and educational technology developers are leveraging these hardware and software innovations as well as ever-expanding computing power and high-speed Internet to build educational innovations for schools. These trends are very specifically focused on educational goals. Table 1.1 illustrates the connections between the hardware and software trends and the educational trends described in this section.

TREND 1: BLENDED AND ONLINE LEARNING As mobile devices and high-speed connections become more readily available in schools and homes, more students are accessing online content and courses. Teachers are blending the use of digital content, OER, and instructional software with the support of LMS in their face-to-face classroom instruction. Furthermore, the enrollments in online schools operating in states is increasing (Digital Learning Collaborative, 2019), and some schools and districts offer a completely online path to earn a diploma. Although controversies such as funding and quality exist, online learning options for K–12 students may reshape schools to offer more flexible learning paths.

Table 1.1 Influence of Hardware and Software Innovations on Current Educational Trends

Hardware and software trends	Educational Trends					
	Blended and Online Learning	Games and Gamification	Personalized Learning	Maker and DIY	Computational Thinking	Immersive Learning
Mobile computing	X	X	X	X	X	X
Digital and open content	X		X			
Learning management systems	X					
Artificial intelligence and learning analytics	X		X			
Robotics and coding				X	X	X
Augmented, virtual, and mixed reality		X				X

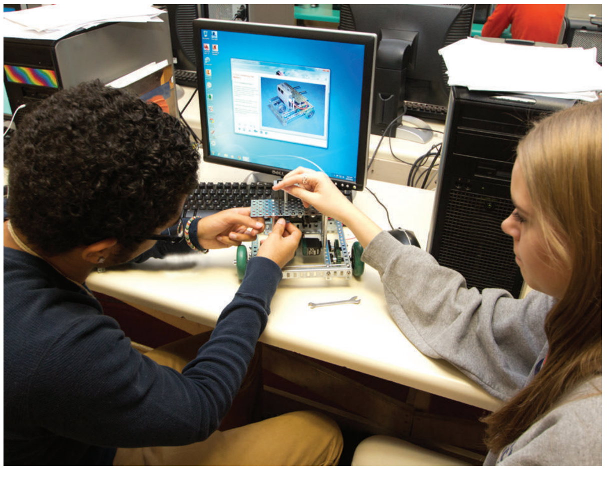
TREND 2: GAMES AND GAMIFICATION In terms of digital content, games have been found to profoundly engage learners and lead to learning gains in subject matter, a key aspect of what researchers call a **serious game**. **Gamification**, or incorporating the motivational aspects of games (e.g., leaderboards and badges awarded for success) into nongame activities, is attracting more attention from both software developers and educators. The hope is that driving interest and rewarding student achievement can increase the time spent on learning activities.

TREND 3: PERSONALIZED LEARNING Learning analytics has driven a fast-growing trend toward **personalized learning systems (PLS)**, or computer-based instructional and management programs, that (1) assess individual student learning needs using complex algorithms and collections of data across students and (2) provide a customized instructional experience matched to each student, often via software offered on mobile computing devices.

TREND 4: MAKER AND DIY A culture of making things and "do it yourself" has led schools to establish **makerspaces**, physical spaces in libraries and other available spaces with digital and mechanical tools and materials where students learn to design, tinker with, and build tangible objects. Multidisciplinary activities can draw from computer and technical education, home economics, STEM disciplines, art, and music. **3-D printers**, often found in makerspaces, build physical models in plastic or other material one layer at a time from 3-D modeling or CAD software. Some makerspaces are full of mobile computing devices and technologies such as Arduinos, Raspberry Pi, and scanners; others repurpose items such as newspaper and cardboard. **Making** is less about the specific outcome and more about the process of design, inquiry, and creating.

TREND 5: COMPUTATIONAL THINKING With recent emphasis on STEM, robotics, computer programming, and making, educators have begun to coalesce around the value of having students learn computation thinking skills. Definitions of **computational thinking** vary but the aim is to develop students with knowledge and skills in problem solving, design, inquiry, abstraction, quantitative reasoning, data analysis and interpretation, modeling, computer programming, pattern identification, conditional logic, algorithms, and symbol systems. Students use creative ways of thinking in computer science to break down, model, and explore phenomena and to identify explanations or solutions through the use of computers. The Computer Science Teacher Association (CSTA) is a resource for current concepts, curricula, and assessments regarding computational thinking, but all teachers should learn about it because being a "computational thinker" is one of the 2016 ISTE Standards for all students. Figure 1.4 shows a girl and a boy involved in STEM activities that develop their computational thinking skills.

Figure 1.4 Girls and boys learning through robotics



TREND 6: IMMERSIVE LEARNING New environments and mobile digital tools that use augmented, virtual, and mixed reality are being created to integrate the physical world with virtual elements to engage learners in understanding conceptual or hard-to-replicate phenomena. For example, students use an AR app to hover their tablets over images of famous paintings, which calls up audio and text about the artist's techniques. EcoMUVE, a project from Harvard University, employs virtual reality technologies to support middle school students' research of ecosystems. SimBio is a virtual biology lab offering simulated open-ended experiments. Virtual reality has become more mainstream in society, which is demonstrated by the availability of low-cost Google Cardboard viewing devices that pair with mobile phones. News agencies, such as *National Geographic* and the *New York Times*, publish AR and VR extensions to many of their news stories. Google Arts & Culture help teachers take students on virtual field trips (Google, 2021). NASA also offers several free AR and VR apps (NASA Jet Propulsion Laboratory, n.d.).

Today's Essential Conditions That Shape Technology Integration

Learning Outcome 1.3 **Articulate the impact of leadership, politics and policies, infrastructure, safety, and equity and social justice conditions on current uses of technology in education. (ISTE Standards for Educators: 2—Leader; 3—Citizen; 4—Collaborator; 5—Designer)**

Educators must recognize that teaching, including efforts in technology integration, occurs within a myriad of contexts from communities to the classroom to cities, states, and nations. These contexts with their subtleties and complexities influence what educators can accomplish. The following sections describe these contextual conditions organized within five areas—leadership, policies, infrastructure, safety, and equity and justice—that influence technology adoption and integration in schools today, as summarized in Table 1.2.

Leadership Conditions

Educational leadership is a primary condition that influences school-based technology integration. Leaders should be involving educational stakeholders in all technology planning and visioning activities. The vision affects all the ways that technology is used in teaching and learning in a school.

Table 1.2 Conditions That Shape the Environment for Using Technology

Conditions	Implications for Educators, Students, and Their Families
Leadership	
Technology vision	• Educators, students, and parents should be involved in shared leadership.
Community engagement	• Technology vision should be learner-focused and community-informed.
Digital literacy/digital citizenship needs	• All students must develop digital literacy to become digital citizens.
Student-centered, technology-based pedagogy	• Students become engaged in active, inquiry-based technology-supported lessons.
Political	
Technology policies	• National, state, and local technology plans and policies guide schools.
Teacher and student accountability requirements	• Accountability emphases often drive technology use.
Consistent and adequate funding	• Schools and district must be creative funders for technology hardware, software, and professional learning.
Infrastructure	
Internet and devices	• Schools must establish strong Internet Wi-Fi and access to digital devices in school and in students' homes and communities.
Software and digital content	• Schools and teachers must review software and content to ensure it is high-quality.
Technology support	• Teachers require human support for technical problems, lesson design, technology selection, and professional learning.

Table 1.2 *(Continued)*

Conditions	Implications for Educators, Students, and Their Families
Safety	
Data and privacy	• It is incumbent on schools to safeguard students' data and privacy.
Online safety	• Acceptable use policies are required.
Health and well-being	• Technology overuse can cause unhealthy ailments.
Digital identity	• Colleges, universities, and employers examine students' and teachers' digital footprints.
Equity and Justice	
Digital equity	• It is inequitable and socially unjust when technology use by many student subgroups is limited to remedial rather than empowering learning purposes. • Schools and teachers should advocate for digital equity.
Students with special needs	• Methods to allow equal access for learners with special needs are often built into software and devices.

TECHNOLOGY VISION Research demonstrates that effective technology leadership is a significant predictor of teachers' and students' use of technology in schools (Hughes et al., 2016; Schrum & Levin, 2013). Administrative leaders such as superintendents and principals are effective technology leaders when they lead collaborative processes for technological goal setting and visioning with stakeholders, such as teachers, staff, parents, students, and community members. Furthermore, research shows more success with technology in classrooms when the technology visions of schools or districts are learning focused, curricular focused, and preplanned (Dexter, 2011; Warschauer et al., 2014). Implementation of a technology vision should involve all stakeholders, such as parent information meetings, administration of ongoing surveys, systematic teacher professional learning, and evaluations of progress. Formal leaders should empower teachers and others to be part of a **distributed leadership** network that collectively shares responsibility for achieving goals. Teachers should seek out their own technology leadership contributions, such as serving on technology committees and engaging with peer colleagues (Dexter, 2011). (See Chapter 3 for more ideas.)

COMMUNITY ENGAGEMENT Social connections with a school's community base are fundamental in identifying and then attaining the school's technology goals and vision. Explicit outreach and information sharing with the community, including parents, elders, and business owners, can build a vision and goals that reflect community needs. Noguerón-Liu (2017) describes how schools considering 1:1 computing initiatives must realize that nondominant parents' (such as new immigrant families) understandings of digital tools may be in conflict with school-based assumptions of how tools should be used at home. All viewpoints should be considered. We also recommend that the technology plans of teachers, schools, and districts be live, online, interactive sites where goals, accomplishments, and needs are clearly articulated and available to the public when possible.

DIGITAL LITERACY AND DIGITAL CITIZENSHIP The increasing role that technology plays in all areas of our society makes it ever more essential that students become critical consumers of technology resources and demonstrate **digital citizenship**, the use of technology resources in safe, responsible, and legal ways. As more digital resources are created, students need to develop **digital literacy** skills, which enable them to (1) access, evaluate, and manage information, (2) analyze digital media for their underlying message and purposes, (3) use media creation tools for expression, and (4) understand legal and ethical uses of digital technology. A national survey of eighth-graders indicate disparity in technology literacy by race/ethnicity, eligibility for school lunch, disability status, and English language learning status (National Assessment of Educational Progress, 2018). It is a socially just responsibility for all teachers to begin developing all students' digital literacy within their instructional courses.

STUDENT-CENTERED TECHNOLOGY-BASED PEDAGOGIES Educators continue to debate the roles of traditional, teacher-directed methods versus student-centered, constructivist methods. Long-used and well-validated teacher-directed uses of technology can address content standards, but we advocate for inquiry-based, student-centered, constructivist methods. Research reveals that constructivist approaches can lead to higher learning gains and builds long-term, flexible knowledge. For example, in a comparison of a story-based and game-based curriculum to teach persuasive writing, learning gains and engagement for students were significantly higher in the game-based curriculum (Barab et al., 2012). Chapter 2 thoroughly reviews how learning theories lead to different technology-based pedagogy.

Political Conditions

We all live in a political world with frequent changes in national, state, and local governance. Public schools were established based on democratic ideals of free, universal, and nonreligious schooling available for all. Federal governance through the U.S. Department of Education and state and local governance have varying responsibilities toward the organization, funding, and curriculum of public schools.

VISIONARY TECHNOLOGY POLICIES Technology integration is influenced by national, state, and local policies and priorities. The U.S. Department of Education's Office of Educational Technology creates a national educational technology plan (NETP) about every 4 to 6 years. The 2016 National Educational Technology Plan, Future Ready Learning: Reimagining the Role of Technology in Education (Office of Educational Technology, 2016), set forth the vision and plan for the nation for learning with technology. This plan positions leadership, teaching, and assessment as crucial elements to ensure visionary learning with technology that is enabled through accessible digital devices and resources for everyone with connectivity (see Figure 1.5). Each state has an educational technology plan, and districts create technology plans that assist in setting local goals and securing grants and other funding. As an educator, you can also create a classroom technology plan to help guide your own technology integration efforts.

TEACHER AND STUDENT ACCOUNTABILITY FOR QUALITY AND PROGRESS The federal-level Every Student Succeeds Act (ESSA) offers more decision-making authority to the states. States can adopt the Common Core State Standards or other challenging academic standards. States still must test students in reading and math in grades 3 through 8 and once in high school, but there is more latitude in regard to which tests to use. Schools may be able to use some Title 1 funds for schoolwide programs, which include educational technology. A strong trend toward using technology in ways that help students pass tests and meet required standards rather than support more innovative teaching strategies continues. Teachers might be influenced to use technologies only if they address accountability goals.

CONSISTENT AND ADEQUATE TECHNOLOGY FUNDING Educational funding is not consistent nor equitable across schools, which means that funds are not always available for technology hardware, software, and professional learning. Funding should be considered an ongoing expense in the budget, and it should prioritize technology resources that support enacting the vision and meeting the goals set in a district technology plan. The federal E-rate program provides discounts for high-speed, wireless Internet connectivity for schools and libraries, especially those in rural areas or with large student populations qualifying for free or reduced-price lunch. To lower costs, some technology advocates suggest shifting from textbooks to OER, or eliminating computer laboratories and copy machines, creating partnerships to leverage purchasing discounts or share infrastructure or staff, or reconsidering staff responsibilities to streamline roles and avoid new staff costs. Considerable care needs to be taken to ensure that teacher workloads are not expanded when lowering costs. For example, in a case

Figure 1.5 U.S. National Educational Technology Plan Infographic

Office of Educational Technology (2016). *Future ready learning: Reimagining the role of technology in education*. U.S. Department of Education. http://tech.ed.gov/netp/

study of a high school special education teacher using one-to-one iPads in her classroom, Ok and colleagues (2017) found that a shift from textbooks to open educational resources essentially shifted the responsibility to the teacher to find, research, choose, and request purchases of apps. The teacher reported this responsibility to be prohibitively time-consuming.

Infrastructure Conditions

The availability of technology is a necessary condition for teachers to be able to integrate it into their curricula. Schools can establish a technological environment for teaching and learning, but such environments are not always equal given the leadership and political conditions previously described.

INTERNET AND DEVICES For educators to use technologies in their classrooms, schools must build a robust technological infrastructure. The elements in this infrastructure should be driven by the vision and goals of a technology plan. At a minimum, schools should establish ubiquitous, strong Internet Wi-Fi connectivity and access to digital devices for teaching and learning. The goals of each individual school or district should guide the specificity of the infrastructure. For example, some schools provide Internet connectivity for children at home. Some schools allow students to bring their own devices and others provide one-to-one tablet or laptop environments, both increasing mobile-supported learning.

SOFTWARE AND DIGITAL CONTENT Schools must make available high-quality digital software and content. Some schools are using open educational resources or purchasing digital textbooks and other apps to support teaching and learning. Teachers can advocate for content resources that have accurate, current, rigorous content with a wide scope to meet a range of learners' needs. Software should involve learners with agency in their decision-making regarding content and learning paths, should prioritize minds-on activities such as puzzles or inquiries, and should offer interactivity where learners build and create knowledge.

TECHNOLOGY SUPPORT Educators also need support staff to assist with technical difficulties, technology-supported lesson design, technology selection, and professional learning opportunities focused on technology. Some schools have dedicated technology specialists who contribute to meeting all these responsibilities. Some schools must share support staff across one or more other schools. Large schools, in contrast, could have multiple staff in these support roles. Librarians and media specialists can also offer technical assistance. Finally, some support could be outsourced to companies that provide infrastructural resources to the school; these companies could accommodate technical inquiries via phone calls, emails, web chats, or videoconferencing.

Safety Conditions

Technology is not neutral; it may have both positive and negative impact within schools. Educators must recognize the conditions described in this section that may threaten the safety and well-being of teachers, students, and their families. Every school can begin to address these conditions through sound policies and a planned, ongoing education program to make teachers and students aware of these concerns and to ensure safety.

PROTECTING PERSONAL DATA AND PRIVACY As more and more digital data are generated in the daily activities of educators and learners, data use policies ensure the appropriate safeguarding of student data. Typically, the protected data might be in **Student Information System (SIS)** software or might be personally identifiable information, such as a student name or picture, in online software like blogs or wikis. Several federal laws have protections for student education records and personal information, such as the Family Educational Rights and Privacy Act (FERPA), the Protection of Pupil Rights Amendment (PPRA), the confidentiality provisions in the Individuals with Disabilities Education Act (IDEA), and the Children's Online Privacy Protection

Act (COPPA). A data use policy helps educators understand what data are acceptable to access and use and in what ways. Furthermore, schools install **firewalls**, software that blocks unauthorized access to classroom computers and require authenticated log-in to all computers. Schools and districts must constantly educate teachers and students on strategies to prevent **phishing** attempts, which are emails that falsely claim to be from a legitimate source in order to glean private information. For example, a teacher could receive a message purporting to be from the school district's information technology department asking all users to update their records with passwords and other information. If the teacher supplies this information, the phisher can access the teacher's account, which could contain a great deal of private information. Educators should always check email addresses carefully before opening attachments, never log in to a site or provide private information when an email requests it, and download software only from reputable company websites.

ONLINE SAFETY The federal Children's Internet Protection Act (CIPA) requires school districts that accept E-rate funds to build their Internet infrastructure, which includes most districts, to block or filter children's access to obscene, pornographic, or harmful pictures on the Internet. Filters are not 100% accurate, so students also need to be educated as to what information is acceptable to access. To address these concerns, schools are requiring students, parents, teachers, and staff to sign an **acceptable use policy (AUP)** that outlines appropriate use of school technologies for students and educators.

HEALTH AND WELL-BEING Potential problems such as hearing loss from headphone use or eye strain from gazing too long at digital screens have been identified and continue to be studied. Time spent at video games and computer work is time taken away from actual physical activity, which can contribute to obesity and decline in fitness. Online harassment in digital environments, known as cyberbullying is defined as involving aggression, repetition, and imbalance of power, and technology enables the online persistence and visibility of acts of cyberbullying (Boyd, 2014). It mirrors similar bullying on school campuses.

DIGITAL IDENTITY Students and educators build a digital footprint as they use public online systems, such as social networking. Students are often unaware that college and university admissions personnel and prospective employers review and consider available web-based information about students. Teachers who have their own social networking sites have encountered criticism or even been fired for ill-advised personal posts and contact with students. Many schools now have social media policies that outline rules regarding educators' use of social media.

Equity and Social Justice Conditions

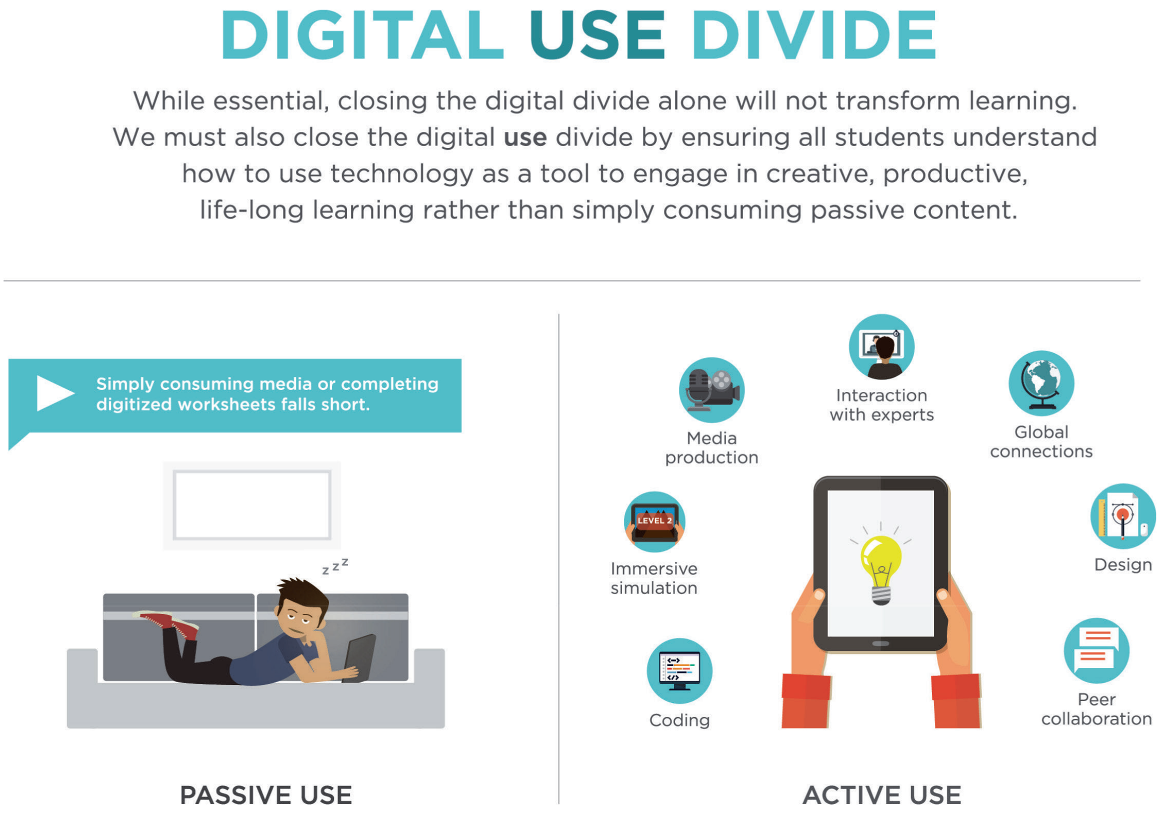
Technology is a double-edged sword, especially for education. It presents obvious potential for changing education and empowering teachers and students but can also further divide members of our society based on race, ethnicity, or national origin; sex; sexual orientation or gender identity or expression; disability; English language ability; religion; socioeconomic status; and geographical location. Teachers lead the struggle to make sure that their technology use promotes rather than conflicts with the equitable, socially just goals of a democratic society.

DIGITAL EQUITY Originally when discrepancies in access to technology resources occurred among groups of different socioeconomic, race, or gender distributions, it was referred to as a **digital divide**. More recently, the term **digital inequity** has expanded the concept from solely unequal access to the unequal educational opportunities involving technologies. Educators must be sure that subgroups of students do not have disproportionally different access to active versus passive technology-supported learning opportunities in schools. For example, Hughes and colleagues (2015) discovered inequities in home and school technology use according to students' race and school urbanicity. Figure 1.6 exemplifies that passive and active digital uses are very different, and we must ensure that all students engage in active technological uses. Inequities result in women and people of color earning far fewer degrees in **science, technology, engineering, and math (STEM)** areas (Musu-Gillette et al., 2016) and entering STEM careers at lower rates than men and White people. Programs such as Black Girls Code or Girls Who Code enable young girls to learn computer programming and meet women role models. Teachers can best battle inequity by involving all your students in inquiry-based, empowering digital activities.

EQUITY FOR STUDENTS WITH SPECIAL NEEDS There is an increasing emphasis on **accessibility** in the development of technological hardware, software, apps, learning environments, and digital content using **universal design**. Technology is intended to be used universally by all learners including students who have disabilities, are English learners, or are in locations with low availability of Internet or electricity. For example, technological resources can have built-in text-to-speech capabilities; variable font size, color, and type manipulations; screen zooming; multimedia output (video, audio, text); translation capabilities; high-performance rechargeable batteries; and built-in Wi-Fi. Students with disabilities who have **individualized education programs (IEPs)** could have even more specific assistive technology resources included in the program; if so, providing these resources is guaranteed by federal laws.

Figure 1.6 Digital Divide Infographic

Office of Educational Technology (2016). *Future ready learning: Reimagining the role of technology in education*. U.S. Department of Education. http://tech.ed.gov/netp/



CHAPTER 1 SUMMARY

The following is a summary of the main points covered in this chapter.

1. **The "Big Picture" of Educational Technology**
   - This chapter's big-picture review provides an important framework for viewing the field and consists of key terminology, reflections on the past, considerations about the present, and a look ahead to the future.
   - Important definitions in the field are:
     - Educational technology—Technology resources leveraged to support educational processes involved in addressing teaching and learning.
     - Integrating educational technology—The process of identifying educational problems of practice and matching those with technological resources as possible solutions, using the resources as educational technology in the classroom, and assessing impact on the identified problems.
   - The educational computing/technology past comprises six eras: the mainframe era (1950–late 1970s); the microcomputer era (late 1970s–1993); the Internet era (1990s); mobile technologies, social media, and open access (2001 and continuing); the personalized, adaptive learning era (2008 and continuing); and the digital justice era (2019–onward).
   - We have learned the following from the history of technology in education: No technology is a panacea for education; teachers usually do not develop technology materials or curricula; "technically possible" does not equal "desirable, feasible, or inevitable"; technologies change faster than teachers can keep up; many technologies do not change educational practices; and teachers will always be more important than technology.
2. **Established and Emerging Educational Technology Trends**
   - Trends leveraged by hardware and software innovation include mobile computing, digital and open content, learning management systems, artificial intelligence and learning analytics, robotics and coding, and augmented, virtual, and mixed reality systems.
   - Educational trends leveraging hardware and software innovations include blended and online learning, games and gamification, personalized learning, maker and DIY, computational thinking, and immersive learning.
3. **Today's Essential Conditions That Shape Technology Integration**
   - The following shape technology integration:
     - Leadership conditions such as technology vision, community engagement, digital literacy and digital citizenship, student-centered technology-based pedagogy.
     - Political conditions such as national, state, and local technology policies; teacher and student accountability for quality and progress; and consistent and adequate technology funding.
     - Infrastructure conditions including Internet and devices, software and digital content, and technology support.
     - Safety conditions related to data and privacy, health and well-being, and digital identity.
     - Equity and social justice conditions including digital equity and equity for students with special needs.

TECHNOLOGY INTEGRATION WORKSHOP

Apply What You Learned

This workshop helps you connect more deeply with the content and concepts introduced in this chapter. An important part of the workshop is for you to personalize the ideas from your own experience as well as consider them in terms of the teaching scenario that opens the chapter.

- Prior to reading this chapter, consider how might you have explained the concept *educational technology* to a classmate or your professor. Try to capture in words, a picture, or a figure what your definition might have been. Now, review the definition introduced in this chapter, as summarized in Figure 1.1, and identify the overlaps and gaps between your definition and ours. Any identified gaps are opportunities for you to consider and expand the concept of educational technology.
- Re-review the opening Technology Integration in Action scenario. Based on how Ms. Thomas describes her technology-supported practices across her career,

try to capture in words, a picture, or a figure what you infer her definition of *educational technology* might have been. Identify the overlaps and gaps between Ms. Thomas's inferred definition and ours. How might any identified gaps impact her technology-supported practices?

- Generate a few examples of Ms. Thomas's practices that have been influenced by the established or emerging technological and educational innovations, as summarized in Table 1.1.
- Conjecture about the unsaid backstory of Ms. Thomas's technology-supported practices across her career. First, re-review the conditions that shape how technology can be integrated into practice, as summarized in Table 1.2. Next, identify (1) some elements across these conditions that would have been required for Ms. Thomas's success and (2) some elements across these conditions that you would want to ask her questions about. For these latter areas, state your queries in question form.

CHAPTER 2

Theory into Practice

EDUCATIONAL PROCESSES FOR TRANSFORMATIVE TECHNOLOGY INTEGRATION

Learning Outcomes

After reading this chapter and completing the learning activities, you should be able to:

2.1 Identify the theorists and beliefs associated with directed and social constructivist learning theories and how these theories contribute to pedagogy and technology integration strategies. (ISTE Standards for Educators: 1—Learner; 5—Designer)

2.2 Contrast directed, social constructivist, or combined technology integration pedagogies. (ISTE Standards for Educators: 1—Learner; 5—Designer)

2.3 Identify content and technology standards that guide teachers' design of curriculum and technology integration strategies for student learning and growth. (ISTE Standards for Educators: 1—Learner; 5—Designer; 6—Facilitator)

TECHNOLOGY INTEGRATION IN ACTION:

The Role of Learning Theory

Strategy A: Preparing Students for State Tests

One of Mr. Ng's responsibilities as mathematics department chair was helping all teachers make sure their students did well on the mathematics portion of the state's Test of Essential Skills for Success (TESS-M). Mr. Ng and the other math teachers were determined that every student in the school would pass the TESS-M. They also decided that they would not just "teach to the test." They wanted the students to have a good grounding in math skills that would serve them well in their future education.

From practice test scores he had seen, Mr. Ng realized that too many students needed help to provide individual coaches or tutors for each one, and he disliked the idea of making all students work on skills only some of them needed. At a school he had visited in another district, Mr. Ng was impressed with how teachers relied on a computer-based system that included drills, tutorials, simulations, and problem-solving activities that they could access in their classrooms and the computer lab.

One of the benefits of the system was that students could solve math problems and teachers could get a list of skills with which each student was having trouble. Then the system would recommend specific activities, on and off the system, matched to each child's needs. The activities ranged from practice in very basic math skills to solving real-life problems that required algebra and other math skills. Mr. Ng persuaded his principal to purchase a year's subscription to this system, and he and the other math teachers agreed on ways they would use it to support their classroom instruction.

That year, almost every student at the school passed the TESS-M. The math teachers agreed that the computer-based activities had played a key role in students' preparation. They liked the way those activities helped target students' specific needs more efficiently without overemphasizing test taking. Mr. Ng asked the principal to make the system a permanent part of the school's budget.

Strategy B: A Simulated Family Project

Ms. Rodriguez's middle school math students are usually fairly good at mathematics skills, although based on various practice tests, some would have trouble passing the state's TESS-M. She liked to do at least one ongoing project each year to show students how their math skills apply to real-life situations. Ms. Rodriguez also wanted them to learn to work together to solve problems just as they would be doing in high school and college and in work situations when they graduate.

The first activity Ms. Rodriguez implemented at the beginning of each year was to have her students work in small groups to simulate "families." The groups designed the families—including deciding on the family size, type of family members (i.e., children, parents, grandparents, caregivers), number of wage earners and the jobs they hold—and created a monthly budget in a spreadsheet template. Ms. Rodriguez designed a template to show income earned from the jobs and estimated monthly expenses for each of them and for the designed family. To select jobs, the groups consulted online newspaper Help Wanted sections, websites for job-seekers, and adults they knew to get an idea of what positions were available and how much they paid.

To estimate expenses, they researched online newspaper and real estate ads to see how much it cost to rent a house or an apartment in an area where their simulated family would live. Throughout the year, Ms. Rodriguez gave each group unexpected expenses (e.g., the dog gets sick, the roof leaks); the students then adjusted their spreadsheet budget to compensate for the extra expenses. If a group either had a surplus or went into debt, she made the students consider a range of investments, loans, and relocation or selling of assets, which they did by researching available interest rates and prices and adding their choices to their spreadsheet budgets.

Toward the end of the year, Ms. Rodriguez had students calculate estimated taxes on their earnings. Finally, they prepared a report using presentation software that showed charts of their spending and what they learned about "making ends meet." The students always told her this was the most meaningful math activity they had ever done.

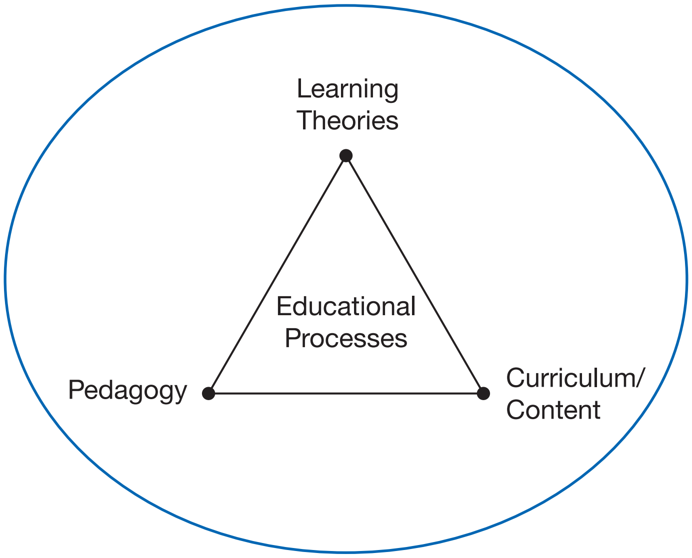
Introduction

This chapter introduces three types of educational processes that impact how technologies may support instruction and learning. These are learning theories based on the sciences of human behavior, pedagogical or instructional practices that complement learning theories, and the curriculum standards or content knowledge that inform learning objectives or goals. These three areas form the first triangle of our Framework for Integrating Educational Technology (see Figure 2.1), as introduced in Chapter 1. In this text, learning theories and their corresponding pedagogies are grouped into two categories: (1) directed and (2) social constructivist.

Theorists and practitioners reflect two contrasting views of how instruction and learning should take place:

- *Directed.* Teachers should transmit a predefined set of information to students through teacher-organized activities. This view is based on **objectivism**, a belief system grounded primarily in behaviorist learning theory and the information-processing branch of the cognitive learning theories.
- *Social constructivist.* Teachers should build inquiry, discovery, and experiential learning into their instruction so that learners can generate their own knowledge

Figure 2.1 Educational Processes: A Framework for Integrating Educational Technology. This chapter provides more information on the three educational processes: learning theories, pedagogy, and content/curriculum. Attending to these educational processes help teachers **identify problems of practice** that can serve to guide the lesson designs that involve the use of technology. This is the first part of the framework for integrating educational technology.



through experiences while teachers serve as facilitators. This view is based on **constructivism**, which evolved from other branches of thinking in cognitive learning theory, and social theories that acknowledge the importance of how learners are situated in the world, such as prioritizing all students' culturally rich knowledge and skills.

Both directed instruction and social constructivist–based instruction approaches are based on the work of respected learning theorists and psychologists who have studied both the behavior of human beings as learning organisms and the behavior of students in schools and classrooms.

Curriculum and technology standards differ by grade level and subject areas, and each state may adopt different standards. Familiarity with the curriculum enables teachers to identify potential areas of need that available technologies may support.

Learning Theory Foundations of Directed Pedagogical Models

Learning Outcome 2.1 Identify the theorists and beliefs associated with directed and social constructivist learning theories and how these theories contribute to pedagogy and technology integration strategies. (ISTE Standards for Educators: 1—Learner; 5—Designer)

Directed models of integrating technology were derived primarily from a combination of four theorists and theories—behaviorist, information-processing, cognitive-behaviorist, and instructional design theories. This section summarizes the basic concepts associated with these theories and their implications for pedagogical practices and technology integration.

Behaviorist Theories

These theories, among the earliest explanations for how people learn new things, are based primarily on the work of B. F. Skinner (1904–1990). Before Skinner, theories of learning were dominated by **classical conditioning** concepts proposed by Russian physiologist Ivan Pavlov, who proposed that behavior is largely controlled by involuntary physical responses to outside stimuli (e.g., dogs salivating at the sight of a can of dog food). By contrast, Skinner's **operant conditioning** theory asserted that people can have voluntary mental control over their responses (e.g., a child reasons that he will be praised if he behaves well in school). Skinner's work showed that observable behaviors are controlled by the *consequences* of actions rather than by events that precede the actions. A consequence is an outcome (stimulus) after the behavior, which can influence future behaviors. Skinner's work made him a highly influential figure in education.

Skinner reasoned that the internal processes inside the mind involved in learning could not be seen directly. Scientific work had not advanced sufficiently at that time to observe brain activity. Therefore, he concentrated on cause-and-effect relationships that could be established by observation. He found that human behavior could be shaped by **contingencies of reinforcement** or situations in which reinforcement for a learner is contingent on a desired response. He identified three kinds of situations that can shape behavior:

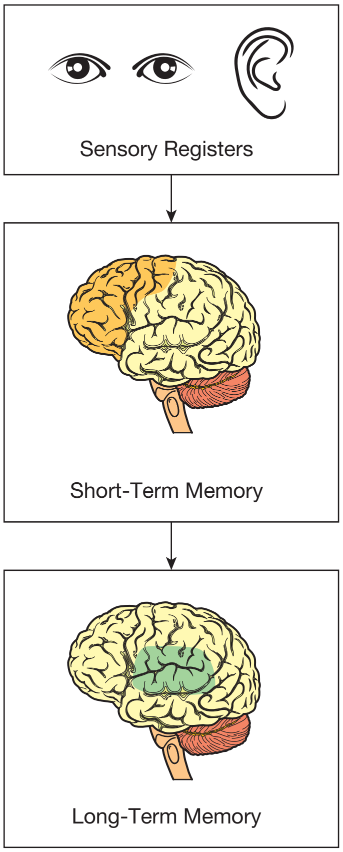
- *Positive reinforcement.* A situation is set up so that an increase in a desired behavior will result from a stimulus. For example, to earn praise or good grades (positive reinforcement), a learner studies hard for a test more often (desired behavior).
- *Negative reinforcement.* A situation is set up so that an increase in a desired behavior will result from avoiding or removing a stimulus. For example, a student dislikes going to detention (negative reinforcement), so to avoid detention again, she is quiet in class more often (desired behavior).
- *Punishment.* A situation is set up so that a decrease in a desired behavior will result from undesirable consequences, such as when a student is given a failing grade (punishment) when he cheats on a test (undesirable behavior), so he is less likely to cheat in the future (desired behavior).

IMPLICATIONS OF BEHAVIORIST THEORIES FOR PEDAGOGY Skinner's influential book *The Technology of Teaching* (1968) presented a detailed theory of how classroom instruction should reflect these behaviorist principles. Many of his classroom management and instructional techniques still are widely used today. Skinner believed that teaching is a process of arranging contingencies of reinforcement effectively to bring about learning. He believed that even such high-level capabilities as critical thinking and creativity could be taught in this way; doing so was simply a matter of establishing chains of behavior through principles of reinforcement. Skinner felt that **programmed instruction** was the most efficient means available for learning skills. Educational psychologists such as Benjamin Bloom also used Skinner's principles to develop what became known as mastery learning:

- We know when people learn only by observing changes in their behavior.
- Behavior is shaped by stimulus-response connections.
- Reinforcement strengthens responses; if people do something and are reinforced for it, they learn to respond in predictable ways.
- Chains of behavior become skills.

IMPLICATIONS OF BEHAVIORIST THEORIES FOR TECHNOLOGY INTEGRATION Most original drill-and-practice software was based on Skinner's reinforcement principles, such as when students knew they would receive praise or an entertaining graphic if they gave correct answers. Much tutorial software is based on the idea of programmed instruction. Because the idea behind drill-and-practice software is to increase the frequency of correct answers in response to stimuli, these packages are often used to help students memorize important basic information, whereas tutorial software gives students an efficient path through concepts they want to learn.

Figure 2.2 Three Kinds of Memory. This model demonstrates that the mind first has sensory inputs, such as information that is seen, heard, felt, or tasted. Second, the mind stores this new information into short-term memory temporarily. Third, if the information is used and retained, it becomes part of long-term memory.



Information-Processing Theories

Educators found Skinner's stimulus–response view of learned behavior insufficient to guide all types of learning, so during the 1950s and 1960s, the first cognitive (as opposed to behavioral) learning theorists began to hypothesize about *processes inside the brain* that allow human beings to learn and remember but could not be observed directly.

Although no single, cohesive information-processing theory of learning summarizes the field, the work of the information-processing theorists is based on a model of memory and storage originally proposed by Atkinson and Shiffrin (1968): The brain contains certain structures that process information much like a computer. This model of the mind as computer hypothesizes that the human brain has three kinds of memory or "stores," as represented in Figure 2.2:

- *Sensory registers.* The part of memory that receives all the information a person senses.
- *Short-term memory (STM).* Also known as *working memory*, the part of memory where new information is held temporarily until it is either lost or placed into long-term memory.
- *Long-term memory (LTM).* The part of memory that has an unlimited capacity and can hold information indefinitely.

According to the model of memory and storage, learning begins when information is sensed through receptors: eyes, ears, nose, mouth, and/or hands. This information is held in the sensory registers for a very short time (perhaps a second) after which it either enters STM or is lost. Many information-processing theorists believed that information could be sensed but lost before it gets to STM if the person is not paying attention to it. According to these theorists, anything that people pay attention to goes into working memory where it can stay for about 5 to 20 seconds. After this time, if information is not processed or practiced in a way that causes it to transfer to LTM, then it, too, is lost. Information-processing theorists believed that for new information to be transferred to LTM, it must be linked in some way to prior knowledge already in LTM. Once information does enter LTM, it is there essentially permanently, although some psychologists believed that even information stored in LTM can be lost if not used regularly.

IMPLICATIONS OF INFORMATION-PROCESSING THEORIES FOR PEDAGOGY

Although subsequent studies have indicated that learning could be more complicated than this model of memory would explain (Schunk, 2012), information-processing views have become the basis for many common classroom practices. Teaching practices based on these concepts include the use of:

1. Interesting questions and eye-catching material to help students pay attention to a new topic, such as a photographs or graphs
2. Mnemonic devices, such as remembering that HOMES stands for the first letters of the five Great Lakes: Huron, Ontario, Michigan, Erie, Superior
3. Instructions that point out (or cue) important points in new material to help students remember, such as linking them to information they already know
4. Visual explanations of abstract concepts, such as from virtual manipulatives or simulations
5. Practice exercises to help transfer information from STM to LTM, such as drill and practice or tutorials.

IMPLICATIONS OF INFORMATION-PROCESSING THEORIES FOR TECHNOLOGY INTEGRATION Computer programs provide ideal environments for the highly structured cueing, attention-getting, visualization, and practice features that information-processing theorists found so essential to learning and remembering. Information-processing theories have also guided the development of **artificial intelligence (AI)** applications, an attempt to develop computer software that can simulate the thinking and learning behaviors of humans. Much of the drill-and-practice functions available within learning software is designed to help students encode and store newly learned information into LTM.

Cognitive-Behaviorist Theory

Robert Gagné (1916–2002) was a renowned educational psychologist who translated principles from behaviorist and information-processing theories into practical instructional strategies that teachers could employ with directed instruction. He is best known for three of his contributions in this area: Events of Instruction, types of learning, and learning hierarchies. Gagné used the information-processing model of internal processes to derive a set of guidelines that teachers could follow to arrange optimal "conditions of learning." His set of **Nine Events of Instruction** was perhaps the best known of these guidelines (Gagné et al., 1992):

1. Gaining attention
2. Informing the learner of the objective
3. Stimulating recall of prerequisite learning
4. Presenting new material
5. Providing learning guidance
6. Eliciting performance
7. Providing feedback about correctness
8. Assessing performance
9. Enhancing retention and recall.

Gagné identified several types of learning as behaviors that students demonstrate after acquiring knowledge. These differ according to the conditions necessary to foster them. He showed how the Events of Instruction would be carried out slightly differently for the five domains of learning outcomes (Gagné et al., 1992):

1. Intellectual skills
   - Problem solving
   - Higher-order rules
   - Defined concepts
   - Concrete concepts
   - Discriminations
2. Cognitive strategies
3. Verbal information
4. Motor skills
5. Attitudes.

The development of "intellectual skills," Gagné believed, requires learning that is akin to a building process. Lower-level skills provide a necessary foundation for higher-level ones. For example, to learn to solve long division problems, students first would have to learn all the prerequisite math skills, beginning with number recognition, number facts, simple addition and subtraction, multiplication, and simple division. Therefore, to teach a skill, a teacher must first identify its prerequisite skills and make sure students possess them. Gagné called this list of building block skills a **learning hierarchy**.

IMPLICATIONS OF COGNITIVE-BEHAVIORIST THEORY FOR PEDAGOGY Instruction based on this theory provides "conditions for learning" by offering activities matched to each type of skill. Students had to demonstrate that they had learned prerequisite skills by demonstrating the type of behavior appropriate for the skill. For example, if the skill was using a grammar rule, students had to demonstrate that they could correctly apply the rule in situations that required it. Gagné's Events of Instruction and learning hierarchies have been widely used to develop systematic instructional design principles. Although his work has had more impact on designing instruction for business, industry, and the military than for K–12 schools, many school curriculum development projects still use a learning hierarchy approach to sequencing skills.

IMPLICATIONS OF COGNITIVE-BEHAVIORIST THEORY FOR TECHNOLOGY INTEGRATION Computer-based methods such as drills and tutorials were deemed useful because they could consistently provide the ideal events and conditions for learning. Gagné and colleagues (1981) showed how Gagné's Events of Instruction could be used to plan lessons using each kind of instructional software function (drill, tutorial, simulation). These authors said that only a tutorial could "stand by itself" and accomplish all of the necessary events of instruction; the other kinds of software required teacher-led activities to accomplish events before and after software use.

Systems Approaches: Instructional Design Models

There are many versions of the systematic design process and many views on what constitutes instructional design (Roblyer, 2015). Saettler (1990) pointed out that modern instructional design models and methods have their roots in the collaborative work of Robert Gagné and Leslie Briggs. These notable educational psychologists developed a way to transfer "laboratory-based learning principles" gleaned from military and industrial training to create an efficient way to develop curriculum and instruction for schools.

Gagné specialized in the use of instructional task analysis to identify required subskills and conditions of learning for them. Briggs's expertise was in systematic methods of designing training programs to save companies time and money in training their personnel. When Gagné and Briggs combined their two areas of expertise, the result was a set of step-by-step processes known as a **systems approach to instructional design**, or *systematic instructional design*, which came into common use in the 1970s and 1980s. Designers created an instructional system by stating goals and objectives; analyzing a task to decide on learning conditions; aligning assessment and instructional strategies with goals and objectives; creating materials that deliver strategies; and testing and revising materials before finalizing them.

Theorists and ideas associated with the development of the instructional design process include Mager (instructional objectives), Glaser (criterion-referenced testing), and Cronbach and Scriven (formative and summative evaluation). Other major contributors to modern instructional design models include Merrill (component display theory) and Reigeluth (elaboration theory).

IMPLICATIONS OF SYSTEMS APPROACHES FOR PEDAGOGY Systems approaches to designing instruction have had great influence on training programs for business, industry, and the military but somewhat less on K–12 education. However, performance objectives and sequences for instructional activities are still widely used. Most lesson planning models call for performance objectives (sometimes called behavioral objectives) to be stated in terms of measurable, observable learner behaviors.

IMPLICATIONS OF SYSTEMS APPROACHES FOR TECHNOLOGY INTEGRATION Most directed models for using technology resources are based on systems approaches; that is, teachers set objectives for a lesson and then develop a sequence of activities.