Chapter 1
Rethinking Learning in the Rapid Developments of Neuroscience, Learning Technologies, and Learning Sciences

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"If we teach today's students as we taught yesterday's, we rob them of tomorrow."

—John Dewey

Abstract In this chapter, we discuss the purpose of this book and provide an overview of evolving discussions on the definitions of human learning, the processes of learning, and the methods to assess learning based on new advances and discoveries in learning sciences, learning technologies, and neurosciences.

Introduction

As technology becomes increasingly integrated into our society, cultural expectations and needs are changing. Social understanding, family roles, organizational skills, and daily activities are all adapting to the advances of ever-present technology, resulting in changes in human brains, emotions, and behaviors. An understanding of the impact

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of technology upon our learning and lives is essential if we are to educate children adequately for the future and plan for meaningful learning environments for them.

The purpose of this book is to provide an overview of some changes from a wide variety of perspectives. Designed for students in the fields and interdisciplinary areas of psychology, neuroscience, technology, computer science, and education, this book provides insights for researchers, professionals, educators, and anyone interested in the integration of mind, brain and technology in learning. The book guides readers to explore alternatives, generate new ideas, and develop constructive plans both for teaching, learning, and for future educational needs.

For over 2000 years, philosophers and scientists have used various technologies to understand and enhance human learning in terms of what, where, when, how, and why a person learns. Historically, research using learning technologies has been limited to behavioral observations, but many questions have extended beyond observable phenomenon: When is memory the same as or different from learning? What helps people learn, will or interest? What associations and technologies help people learn? What is the role of prior knowledge? What do people learn better on their own, and what with learning technologies? The rise of technology has increased the complexity of these issues, as technological innovations bring access to new methods of learning and interactions. At the same time, specialized new technologies are also providing new insights directly into the processes of learning, as scientists investigate learning within the brain.

This chapter will begin with an overview of early learning theorists and their contributions to the understanding of learning. Following this foundational work, we discuss opportunities to extend learning through new technologies. The chapter concludes with a look at neural correlates of learning, social and technological connections of learning, and student learning skills in a digital age.

Evolutions of Learning Theories from a Historical Perspective

Ancient Greek reflections on technology (i.e., *techne*) can be found in the thesis that technology learns from or imitates nature (Plato, Laws). Discussions of how people learn date back to Plato (428–347 BC) and earlier. Plato proposed the question: How does an individual learn something new when the topic is brand new to that person? (Phillips & Soltis, 2009). As is known of the *Theory of Recollection* or *Platonic epistemology* (Silverman, 2014), Plato answered his own question by stating that knowledge (i.e., *episteme*) is present at birth and that all information learned by a person is merely a recollection of something the soul has already learned previously. Plato described learning as a passive process, and his theory has elicited more questions in terms of how an individual gained the knowledge in the first place. It is important to note that while Plato differentiated between techne and episteme, he also viewed them as having connections.

In the days of Aristotle (384–322 BC), the ability to read and write was primarily limited to the wealthy and elite. Memory was an important skill for transfer of knowledge, and one upon which Aristotle focused his studies. Aristotle's view of learning, known today as associationism, embraced the idea that humans learn through cognitively linking concepts (e.g., "sun" brings up images of "bright"; "soft" might inspire thoughts of the opposite concept, "hard"). According to Aristotle, associations between concepts were based upon three principles: contiguity (nearness in time and space), frequency (events often experienced together), and similarity (Gluck, Mercado, & Myers, 2008). Plato and Aristotle's philosophies are learning played important roles in some of the dominant learning theories discussed below. Like Plato, Aristotle distinguished (and identified associations) between techne and episteme. For Aristotle, technology imitates nature and, in some cases, completes what nature cannot (physics).

Behaviorism. John Watson (1878–1958) and Edward Thorndike (1874–1949) extended Aristotle's association model, asserting that the primary goal of learning is for a student to respond correctly to a stimulus (e.g., teacher's question). B. F. Skinner (1904–1990), influenced by these theorists and the physical stimulus-response ideas of I. E. Pavlov (1839–1936), connected learning with rewards and external behavior. To behaviorists such as these, learning involved response to a stimulus (Posner & Rothbart, 2007). Skinner's investigations of positive reinforcement were primarily focused on providing positive reinforcement for "correct" responses of on rats and pigeons. Based on his findings, he defined learning as the production of desired behaviors, and denied any influence of mental processes. Learning would be visible when appropriate reinforcement was provided to the student, with an emphasis on reward over punishment as small steps of progress are made (Bransford, Brown, & Cocking, 2000; Gluck, Mercado, & Myers, 2008). BrainPop and ClassDojo are examples of learning technologies that employ both gamification and behaviorism.

Cognitivism. Jean-Jacques Rousseau (1712–1778) suggested that a child's learning should occur naturally, without constant instruction from his elders, and advocated that the child should take the lead. Jean Piaget (1896–1980) built upon this foundation, focusing upon the child's understanding of the world around him as the basis of his learning. According to Piaget, discrepancies between knowledge and discoveries lead students to adjust their understanding and increase their learning. Learning might not be observable, since mental processes such as memory, language, problem-solving, and concept formation are the goal (Ertmer & Newby, 1993). Piaget focused on cognitive development, stating that language follows the knowledge and understanding acquired through cognitive development. Computer games (online and offline) like Quizlet are examples of cognitivism. Such games typically proffer previous knowledge schema in a different way, which produces disequilibrium and a desire to adapt and learn the new information to continue.

Constructivism. Lev Vygotsky (1896–1934) also emphasized the importance of scaffolding new knowledge and understanding upon previous knowledge and beliefs. However, in contrast to Piaget, he hypothesized that learning occurs as meaning is created from experience, and each learner builds his own interpretation of the world. Vygotsky's concept of the zone of proximal development (ZPD) suggested that the amount of external instructional support should be adapted to the needs of the student. Since learning resides within the student, the importance of personal meaning and understanding lead to increased student agency and learning. Many other theories arise in this camp including Gardner's theory of multiple intelligences, in which Gardner suggests that different kinds of intelligence exist in human beings (1983). An example of constructivism in technology can be found in Google Apps for Education, which allows for student-led collaborative opportunities online. Moreover, students can work together collaboratively on group blogs (Blogspot), group presentations (Sliderocket), and webpages (Google Sites).

Connectivism. As technology has become increasingly ubiquitous in modern society, learning needs have changed. George Siemens (2005), in his theory of connectivism, proposed that the digital age is creating new approaches to learning. No longer is learning limited to what is happening within an individual, but it has become a social and cultural phenomenon requiring the ability to manipulate fast changes in information. Critical thinking skills such as synthesis and concept integration, along with the ability to identify connections and patterns, are basic to this learning theory. In addition, the theory suggests that learning may occur in non-human devices; that maintaining accurate, up-to-date information should be central to learning activities; and that decision-making is in itself a learning process (Siemens, 2005). Massive open online courses (MOOCs) comes from connectivist theory (cMOOC). MOOCs utilize open software and systems across the Internet to facilitate learning and sharing.

Schwartz, Tsang, and Blair (2016) presented 26 approaches to help people learn, and they discussed how these approaches would work and when to use them. For instance, elaboration, generation, and excitement help one better remember what ones to remember and what one wants to learn, while hands-on, contrasting cases, and visulization help discoveries. Schwartz et al. (2016) highlighted important components of learning, which include understanding, memory, motivation, expertise, study skills, sense of inclusion, problem-solving, collaboraiton, and discovery.

Extensions of Learning Through Technologies

Learning is commonly discussed as a cognitive process through which humans acquire knowledge or skills. Yet it is a multidimensional activity comprised of numerous sub-processes, including attention, memory, prediction, pattern recognition, reasoning, decision-making, spatial cognition, and social cognition (Bruner, Goodnow, & Austin, 1986). Because the hierarchy of these sub-processes is mediated by context, learning may be defined differently in different situations. For example, a culture that is highly dependent upon oral history and instruction may see learning as memory (Wineburg, 2001). A piano teacher might define learning as repetition (Maynard, 2006), and an elementary math teacher may consider learning to be pattern recognition (Papic, Mulligan, & Mitchelmore, 2011). Each of these elements plays a role in learning, but none independently defines the learning process.

The definition of learning becomes more elusive with the use of networked computing and communications technologies. In addition to traditional classrooms and methods, learning can take place through simulations, remote laboratories, visualization technologies, games, virtual communities, digital libraries, and mixed realities. New technologies have changed the traditional educational boundaries of time, space, and informational access (Borgman et al., 2008). Virtual and augmented reality support new educational possibilities that allow a student to move beyond his immediate environment (Bainbridge, 2007; Parsons, Carlew, Magtoto, & Stonecipher, 2017; Parsons, Gaggioli, & Riva, 2017; Parsons, Riva, et al., 2017). Social media extends the social experience of learning, as online networks parallel those of offline social networks (Dunbar, 2016; Parsons, 2017; Parsons, Gaggioli, et al., 2017). Students have new opportunities to learn in ways otherwise not possible, developing creative pursuits, decision-making, and social learning, and critical thinking skills (Roschelle, Martin, Ahn, & Schank, 2017). Learning has become a complex, continually evolving group of skills that can be applied in a variety of settings.

Technology can provide flexible learning environments and increase learning equity for individuals with special needs. Adjustable screen and font size, along with text-to-speech capabilities, can help individuals with vision difficulties read the text, and can boost the reading skills and understanding of students with specific reading disabilities. The National Education Technology Plan (U.S. Department of Education, 2017b) promotes equity of access to learning, and provides principles and examples that underscore learning specifications set by Congress in the 2015 Every Student Succeeds Act (U.S. Department of Education, 2017a).

As innovative technologies create new learning opportunities, the skills needed to be an efficient learner are changing (Trilling & Fadel, 2009). Nowhere is this more obvious than in the previous century's focus on memorizing facts. The abundance of information that is available at the touch of a button has replaced our need to remember information with a need to sift through and prioritize information quickly. However, the availability of knowledge from multiple technologies may in effect complicate the learning process.

Understanding Learning Through Neuroimaging Technologies

To understand why learning has become more complex than ever, we start with the concept that human learning involves change (Green & Bavelier, 2008). The change takes place through a sequence of patterns and predictions, as the human brain constantly watches for patterns, makes predictions, and then checks to see if the predictions are being met (Bar, 2007; Parsons, 2017). When predictions are violated, dopamine appears to be activated in the substantia nigra and the ventral tegmental areas of the brain, leading to a sense of reward (Hollerman & Schultz, 1998). The association of learning with reward fuels the human desire to learn; and, as learning opportunities are extended and available through multiple technologies, the desire to learn may lead to media multitasking. The prevalent mobile technologies have been labeled multitasking facilitators that support even more multitasking (Pea et al., 2012). Yet, as we seek the rewards of multitasking, we may work against ourselves. Multitasking may interfere with learning (Uncapher et al., 2017), and continued learning while multitasking may change our brain and learning (Poldrack & Foerde, 2007). Although some report on the negative impacts of media multitasking (Ophir, Nass, & Wagner, 2009), others find that media multitaskers perform better on multisensory integration tasks (Lui & Wong, 2012). Lin (2009) has argued the attentional style of media multitaskers may not emphasize attending to the information that is presented as static stimuli (as in the Ophir et al., 2009 study). Instead, media multitaskers may have a greater breadth of attention that inclines them to pay attention to a larger scope of information instead of a specific piece of information. Novel approaches to assessing the impacts of multitasking are needed to clear up inconsistencies in the literature (Lin & Parsons, 2018).

Neuroimaging technology provides insight into the neural underpinnings of specific activities. Studies by Small, Moody, Siddharth, and Bookheimer (2009) suggested that individuals who use technology regularly might use different neural circuits when searching the Internet than when reading text. The authors concluded that decision-making and critical thinking may be impacted by these changes. Other research (Kanai, Bahrami, Roylance, & Rees, 2011) found correlations between the size of online friendship networks and neural areas that are associated with social perception and associative memory: the right superior temporal sulcus, the left middle temporal gyrus, and the entorhinal cortex.

Over the past 50 years, neuroimaging techniques have allowed scientists to move beyond observations of behavior or the mind to observations of cognitive activation in the brain, providing new insights into behaviors and neural correlates that appear to underlie learning. Studies related to both mind and brain have indicated basic principles that are involved in the process of learning.

A human's perceptions and understanding of the world are built on patterns. Sensory input is registered as patterns of perceptions, and may be preserved either as unisensory or as multisensory perceptions. In multisensory patterns, each sense will be preserved independently: the visual patterns that are observed in a friend's facial features and the auditory patterns heard in her voice may be recorded simultaneously, but they may be stored for individual access (Hawkins & Blakeslee, 2004). The brain continuously searches for patterns, and is well adept at discovering them even in the midst of chaos and disorder (Hawkins & Blakeslee, 2004; Kelso, 1997, p. 3). Patterns, or relations between items or events, are stored for access when humans encounter new situations.

As the cortex searches its store of patterns, the neocortex predicts what it expects to see, hear, and feel. When the expectations are violated, learning takes place. Prediction is a primary task of the neocortex (Hawkins & Blakeslee, 2004), and the human drive to predict has been described as a "powerful tool for learning" (Elman, 2009, cited in Misyak, Christiansen, & Bruce Tomblin, 2010).

Advances in technology have fuelled the development of more accurate neuroimaging capabilities, leading to improved scientific understanding of neural functioning. Over the past decade, neuroimaging technology capacities have expanded from the controlled lab environments of the twentieth century to portable neuroimaging devices (Engin, Dalbastı, Güldüren, Davaslı, & Engin, 2007; McMahan, Parberry, & Parsons, 2015; Parsons, McMahan, & Parberry, in press), social neuroscience experiences (Parsons, 2015; Parsons, Gaggioli, et al., 2017; Schilbach, Eickhoff, Rotarska-Jagiela, Fink, & Vogeley, 2008), and virtual reality (Parsons, 2015, 2017; Parsons & Phillips, 2016). The capacity to merge neuropsychological assessments with real-life experiences has supported a more detailed and accurate understanding of neural functioning during learning (Parsons, 2016; Parsons, Carlew, et al., 2017; Parsons & Kane, 2017).

Connecting Learning with Social and Technological Networks

To foster the inclusion of research advances from the neurosciences, Parsons (2017) presented a brain-based cyberpsychology framework that can be applied to cyberlearning via (1) the neurocognitive, affective, and social aspects of students interacting with technology; and (2) affective computing aspects of students interacting with devices/systems that incorporate computation. As such, a brain-based cyberlearning approach investigates both the ways in which educators and students make use of devices and the neurocognitive processes, motivations, intentions, behavioral outcomes, and effects of online and offline use of technology.

Parsons (2015, 2017) argues that past conceptualizations that separate emotion from cognition are wrongheaded and not well supported by scientific findings. He draws upon Antonio Damasio's, Tranel, and Damasio's (1991) Somatic Marker Hypothesis to note the interconnectedness of the two realms. Damasio's et al. (1991) Somatic Marker Hypothesis proposes that emotions may be evidenced in somatic (body) markers, such as rapid heart rate with anxiety or nausea with disgust.

Mills, Wu, and D'Mello (2017) suggested that optimal emotional states may vary according to task. When task performance of adults experiencing either positive or negative affect states was assessed, researchers found that the sad group of participants outperformed the happy group on tests of deep reasoning. These findings emphasize the role of emotions in attention and motivation, which are intricately involved in the learning process (Immordino-Yang, 2016, p. 87).

Humans live in a social world, and social processing is intertwined with emotion. As a result, social context highly impacts learning capacity. While Giacomo Rizzolatti and Vittorio Gallese (as well as some of their colleagues) in Italy (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996) observed the brains of monkeys and noted that particular cells activated both when a monkey performed an action and when the monkey viewed another monkey performing the same action. This resulted in the discovery of "mirror neurons." Research has emerged linking these neurons appeared to abilities such as empathy and the perception of another's intentions (Iacoboni et al., 2005; Ramachandran, 2000; Ramachandran & Oberman, 2006). New fMRI studies involving multiple participants (Konvalinka & Roepstorff, 2012) are producing insights into the neuroscience of socialization. Research findings suggest a large-scale brain network (anterior insula, anterior cingulate cortex, and inferior frontal cortex) activates both when one experiences emotions and when observing another person experiencing an emotion.

Although social media and messaging can be distractions when an individual seeks knowledge through technology, social connections remain an important component of learning. Social interaction is an important factor in cognitive development (Vygotsky, 1978), and the social processes of observation, imitation, and modeling are fundamental to learning (Bandura, 1978). Emotion plays an important role in motivation to learn, decision-making, and problem-solving (Damasio et al., 1991; Immordino-Yang & Damasio, 2007; Parsons, 2017). Because emotions are deeply bonded with social processing (Immordino-Yang, 2017), social and emotional connections have a strong influence on human learning (Immordino-Yang, 2008; Oberman, Pineda, & Ramachandran, 2007, cited in Immordino-Yang & Gotlieb, 2017).

Student Learning Skills in a Digital Age

The skills required for effective learning assume different priorities in learning in a technology immersive environment. When learning with technologies, easy access to continuously updated information minimizes the need for memory work, but requires skill in sifting through information and determining which material is relevant and factual. In addition, the student must know how to access quality informational sources and must self-monitor in order to limit interruptions from social messages, advertisements, online entertainment, and other distractions.

Scaffolding and prior knowledge. Both Piaget and Kamii (1978) and Vygotsky (1978) espoused the view that new knowledge must be constructed from existing knowledge, and that connections with past experience and knowledge can strengthen learning. A variety of technological programs and websites support scaffolding and links to prior knowledge through easily accessible examples and illustrations, tools that support the development of graphic organizers, and opportunities to learn, review, and expand concepts. These tools provide models for the learners, help students visualize the goal to be accomplished, and build a more solid learning foundation (Alber, 2011).

Digital students and agency. Technology provides new opportunities for learners to assume control of their own learning. Whereas traditional students often depended upon an instructor to share knowledge with them, digital students can access a plethora of information from their smartphones, computers, or other technological devices. Throughout the twentieth century, learning theorists have promoted the need for learners to manipulate objects, engage in discussion, and experience schema in order to build mental models of the world (Dewey, 1938; Piaget, 1964; Vygotsky, 1986). Digital learners build knowledge as they observe and interact with virtual and real-time phenomena, build social networks, and make connections between new ideas and prior understandings.

Critical thinking skills. A student in today's digital world does not require the support of a physical classroom in order to learn. Through technology, she has anytime, anywhere access to an abundance of information, including homework, tutoring, and classroom materials. She can explore unlimited environments virtually, and can manipulate objects within the environments. Through interacting with her virtual world, she can explore destinations around the globe, determine how the contents of a cell fit together, and create new ways to travel. Her learning goal will not primarily be to acquire knowledge, but rather to problem-solve and respond creatively to the challenges and needs of a dynamic world.

When students think critically, they are actively engaged in analysis, synthesis, problem-solving, evaluation, and reflection (Mansbach, 2015). The ability to self-regulate reinforces a student's ability to use these processes independently (Tilus, 2012). Instructors in today's schools must use strategies and technological tools that can support growth in each of these skill areas.

Learning Technologies and the Extended Mind

In Parsons (2017) book on cyberpsychology and the brain, he argued that an additional component for our understanding of cognitive, affective, and social processes for cyberlearning is the notion that technology extends the minds cognitive processes. Daniel Dennett (1996, pp. 134–135) has argued that our remarkable cognitive abilities are less a factor of our large frontal lobes than they are an evolutionary offspring of our capacity for extending our cognitive processes into the environment with which we interact. Hence, our enhanced intelligence is due to

> our habit of offloading as much as possible of our cognitive tasks into the environment itself—extruding our minds (that is, our mental projects and activities) into the surrounding world, where a host of peripheral devices we construct can store, process and re-represent our meanings, streamlining, enhancing, and protecting the processes of transformation that are our thinking. This widespread practice of off-loading releases us from the limitations of our animal brains.

This idea is reflected in Clark and Chalmers (1998) development of an "extended mind" theory, in which human cognitive processing consists of complex feedback (including feedforward and feed-around) loops among brain, body, and the external world. Clark and Chalmers argue that a parity-stance should be applied to our considerations of the internal and external mind:

> If, as we confront some task, a part of the world functions as a process which, were it to go on in the head, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the cognitive process (Clark & Chalmers, 1998, p. 8).

Following the "extended mind" approach, cognitive processes are understood as going beyond the brain to software and hardware. Moreover, cognition can be viewed as something being processed by a system that is coupled with the environment (Clark & Chalmers, 1998). In a forward to Clark's (2008) book *Supersizing the Mind*, Chalmers explains how his iPhone has become an extension of his mind:

> A month ago, I bought an iPhone. The iPhone has already taken over some of the central functions of my brain. It has replaced part of my memory, storing phone numbers and addresses that I once would have taxed my brain with. It harbors my desires: I call up a memo with the names of my favorite dishes when I need to order at a local restaurant. I use it to calculate, when I need to figure out bills and tips. It is a tremendous resource in an argument, with Google ever present to help settle disputes. I make plans with it, using its calendar to help determine what I can and can't do in the coming months. I even daydream on the iPhone, idly calling up words and images when my concentration slips. (p. 1)

The point that Chalmers is making is that smart technologies may, under some circumstances, act as a person's cognitive states and beliefs even though they are external to the physical boundaries of the person's brain.

Parsons (2017; in press; see also Chap. 8 in this book) describes the learning technologies of the extended mind in terms of extended cognitive systems that include both brain-based cognitive processes and technologies like tablets, iPads, and smartphones that serve to accomplish functions that would otherwise be attained via the action of brain-based cognitive processes acting internally to the student. In this learning technology of the extended mind, the student's cognitive processes are understood as going beyond wetware (i.e., student's brain) to educational software and hardware. This perspective allows for an understanding of the child's cognition as processed in a system coupled with the child's environment.

How should learning technology extended cognitive systems (i.e., a student performing cognitive processes with learning technologies) be educated and assessed? Heersmink and Knight (2018) argue that educators should teach children to participate in responsible practices of technology use by reverse engineering the cognitive integration, illustrating the steps over which that integration was established, and develop the approaches toward those technologies. This also reflects Wheeler's (2011) reflection on the education of coupled assemblages between the student and technologies of the extended mind. For Wheeler, this focus is entirely in line with the objective of providing the student's brain with the competences necessary for efficient involvements in such assemblages. Wheeler contends that we should aim to educate extended cognitive systems and permit students to utilize technology when they carry out exams.

This approach is reflected in many of the chapters in this book. While most do not explicitly argue for learning technologies of the extended mind, there is an implicit association between students and the cognitive processes that occur while using educational technologies, being immersed in virtual environments, and being evaluated via technologies. As you read through these chapters, we invite you to consider the possibilities of learning technologies that extend students' minds.

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