The Learning Sciences: Where They Came From and What It Means For Instructional Designers

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The goal of this chapter is to describe the Learning Sciences perspective. We address questions about how this perspective emerged, what makes it unique, how it goes beyond previous perspectives on learning, and what research findings and practical tools for the instructional designer result from taking this perspective. To start the chapter, we will take a journey back about 40 years ago.

At that time cognitive psychology was moving into the mainstream of psychology and becoming increasingly entwined with educational applications. Overall, there were three major trends that led to the blossoming of a cognitive psychology relevant to education. First, the departure from purely behaviorist models of psychology allowed for alternative theoretical bases for understanding human learning. Second, the emergence of the interdisciplinary field of cognitive science legitimized mixing and matching approaches from disciplines as varied as computer science, anthropology, linguistics, and philosophy with traditional psychological theories and research methods, which helped bring to the forefrontcontext and culture as key factors in learning (apart from learners' individual psychology, or the particulars of an instructional design). Third, the rise of computer technology opened the doors to a design-mindedness that matched well with teaching and educational psychology, arguably the first design-oriented domains within psychology.

1. Multiple theories of learning in psychology

By the 1970s, psychology was in a marked transition. The dominant paradigm in the early 20th century was behaviorism that focused on linking discrete stimuli to responses through association or reinforcement. However, behaviorism was challenged by a number of alternative paradigms that emerged after World War II. Work in linguistics, information theory, and the emergence of the computer led to ideas that led to the questioning of behaviorism. For example, Chomsky (1959) suggested that behaviorist concepts could not explain the generativity of language. The growing movement towards taking 'thoughts' and 'ideas' seriously as psychological phenomenon was termed 'cognitivism.' As behaviorism was being challenged by cognitive models of thinking, cognitive scientists were building artificial intelligence models of human cognition, and ideas about cognitive development were being developed and studied. For example, Shank and Abelson's (1977) book that melded together artificial intelligence and human thinking about events led to a great deal of research using the script concept to describe how people understood and behaved in real world contexts (e.g., how one conceptualized a visit to a restaurant). Developmental psychologists were busy testing out Piaget's theory of cognitive development to test its explanatory limits. The laboratory for Comparative Human Cognition (LCHC) led by Cole (e.g., Cole & Means, 1981) was busy examining how many of the tasks researchers took for granted as indicative of cognitive skill were viewed differently in other cultures. Meanwhile, cognitive psychologists were investigating the implications of the cognitive architecture of human thinking by studying memory, perception, language acquisition and how people acquire and automatize skills (Gardner, 1985). At every turn, these psychological concepts were suggesting new ways to think about education and learning.

Computer science had a unique role in this mix of disciplines, both as a tool for empirical science and as a platform for intervention. Researchers saw the promise of cognitive science (both psychology and artificial intelligence work) to perhaps change the practices and approaches we had held onto so long in education. John Anderson and colleagues began studying 'intelligent tutoring systems' (Anderson, Boyle, & Reiser, 1985) in which carefully constructed artificial intelligence models of problem solving in a domain such as algebra could direct a computer to provide guidance to learners. These tutoring systems were used to test and refine the induced models of how people think, but they also could be used to try to prompt and support students by solving problems along with them, and then giving feedback when the students' problem solving started to stray. Papert's (1980) book Mindstorms showed how children could invent and create using the LOGO computer language. The premise put forth by Papert was that learning could take place in interaction with tools for construction, and computers could be general purpose tools for letting learners construct artifacts that reflected their understanding of a wide variety of domains. Bransford created the Learning Technology Center at Vanderbilt University in 1984 to develop new ways of using technology (especially video and computers) to help children learn; their interventions drew on what was known about how experts and novices think differently in learning domains, but also drew on ideas about more contextual aspects of learning, such as the use of authentic problems to motivate students. The recognition that technological artifacts and tools could change the way we think and learn was something that went hand-in-hand with the cognitive revolution; rather than simply deliver fine-tuned messages to students about what they should know, the cognitivists began exploring how learners constructed knowledge as they did the work of making sense of the world around them. Along with new theories of learning, new ways of researching needed to be developed because the process no longer was to simply test a theory, but to see how practices changed when new artifacts and ideas were introduced.

2. Broadening the study of learning to include context

Research from several different fronts seemed to point to the central role of context in understanding learning and development. As early as the 1970s, Lee Cronbach (1975) highlighted the weaknesses in psychology's reduction of the study of education to two-way linear interactions between individual differences and educational interventions. What this perspective is blind to is both higher order (nonlinear) interactions, and the effects of learning contexts. Cole's LCHC group found that depending upon the context, what was intelligent behavior could be construed differently. Those studying Piaget's theory found that children's competence on tasks of logical thinking was alterable by changing the context of the task (e.g., McGarrigle & Donaldson, 1974). Those trying to implement tools like LOGO found that success required more than giving children the opportunity to interact with the computer program, and that the effects of a tool like LOGO did not generalize as widely as people thought they might (Pea, Kurland, & Hawkins, 1985). Other attempts to implement what cognitive scientists thought would be effective in the classroom also ran into problems. Researchers studying memory wondered why students did not access the knowledge they had, and set out to discover what it would take to help them access their available knowledge.

The recognition of the importance of context suggested that the unit of analysis for understanding learning had to be larger than the individual person. People learned things with other people and generally learned with culturally developed tools and artifacts. Hence, studying these interactions, tools and artifacts meant considering ideas from fields like sociology and anthropology, semiotics and linguistics as part of the research and theory-building process.

Four somewhat related theoretical ideas emerged to help frame this new understanding. First, there was the rediscovery of Vygotsky's theoretical work as presented in the *Mind and Society* compilation (Vygotsky & Cole, 1978). Vygotsky died in 1934, but his ideas were not widely known outside of the Soviet Union (and were suppressed there). Hence, the ideas were largely unknown in the United States. They contained within them, however, ideas that resonated with the findings of individuals applying cognitive science in the everyday world. First, instead of being secondary, the importance of culture and the artifacts were primary. Both the learning of the individual and the adaptation of the species were tied to cultural artifacts and tools. People's cognitive processes are created in conjunction with the tools of the culture, and at the same time, the tools of the culture are enhanced by the thinking of people and societies. Additionally, Vygotsky's idea of the "Zone of Proximal Development" (ZDP), led people to think differently about learning, assessment, and development. The idea of the ZPD is that the cutting edge of learning is not what student can do individually, but what he or she can accomplish with the help of a more able other.

Out of these ideas, and in particular the idea of the "Zone of Proximal Development", Brown and Campione (1994) developed the Fostering Community of Learners model for teaching science. The approach involved developing group projects around thematic science units that featured (a) distributed expertise among students and (b) activities that create a discourse around topics that looked more like what scientists do than typically classroom science that focuses on vocabulary memorization and "canned" labs.

Also coming out of the renaissance of thinking about Vygotsky was the notion of distributed intelligence (Pea, 1993). As Pea notes, the concept of historically changing tools for thinking that arise from human cultures in Vygotsky's theory fit well with the notion that technologies provided tools that changed thinking processes in people. Pea and others suggested that the transformative potential of new forms of technology that were emerging not only made activities easier, but actually changed how they were carried out. In other words, what was intelligence was actually changed by changing the tools for thinking. Thus, Vygotsky's model also provided a way to conceptualize the transformative impacts of new technology.

Second was the idea of situated learning (Greeno & The Middle School Mathematics Through Applications Project Group, 1998; Kirshner & Whitson, 1997; Lave, 1988; Lave & Wenger, 1991). For example, Lave (1988) who did work cross-culturally and in everyday contexts like grocery shopping found that learning in these informal environments was not something that widely generalized, but tended to be highly tied to the activity context and its meaning for the people involved. Such analysis raised serious questions for traditional schooling, where the learning of students in formal classroom settings would purportedly transfer to new contexts in the everyday world. In contrast, a basic tenet of situated cognition is that in order to promote skill transfer from the learning setting to the "real world" setting in which the skills are expected to be employed, the conditions in the learning setting should be as similar as possible to those that the learner will encounter in the real world.

A third idea was that of anchored instruction (The Cognition and Technology Group at Vanderbilt, 1990). The anchored instruction model arose out of the notion that in order for people to access knowledge, they need not only to experience it, but to experience it such that they can know when to use it. It is "conditionalized" (National Research Council Committee on Learning Research and Educational Practice, Bransford, Pellegrino, & Donovan, 1999) to particular classes of events. Without anchoring the knowledge to situations where the purpose of the knowledge is clear, then is likely to become inert. Ideas like these, and interest in applying knowledge in real contexts led researchers to look for new perspectives. Out of work on anchored instruction came the Adventures of Jasper Woodbury (Cognition and Technology Group at Vanderbilt, 1992), a series of videodiscs (later CD-ROM) that was involved in helping middle school students develop skills in solving complex mathematics problems by presenting the problems to them in simulated real world contexts designed to be of interest to the students.

Fourth, Roger Shank, bolstered by the insights gained from his computer models of how people think in the real world (e.g., Riesbeck & Schank, 1989), started a center for Learning Sciences that focused on developing similarly innovative approaches to professional development and training. Shank is generally seen as the first to use the term *the learning sciences*, but his concept of the learning sciences did not encompass the diversity of perspectives that today make up the field (Hoadley, 2007). In 1991, the *Journal for the Learning Sciences* was started (Kolodner, 1991) and later the *International Society for the Learning Sciences* was formed.

As initiatives like these emerged, they contained some common elements that made traditional research methods problematic; yet researchers felt they were learning something fundamental about how students can learn. Traditional research and evaluation methods, such as randomized experiments, require controlling variables and manipulating only a few things at a time. Traditional program evaluation methods focused largely on outcomes without paying enough attention to the learning of researchers during the process of designing these interventions. Researchers felt they were learning something fundamental about learning as they developed new instructional approaches, and consequently felt the need to develop new methodological approaches. Brown (1992) and Collins (Collins, 1992) created what was initially talked about as design experiments and later more generally described as design-based research (Design-Based Research Collective, 2003). The basic method involved documenting what was going on in an applied setting and examining the impact of complex instructional implementations as they went through different phases of design and development. For example, the second author has been involved in an initiative that involves the development of engineering design challenges for middle school students. In that initiative, both the process of developing the modules and the examination of their effectiveness are being studied. Initial analyses involve examining frame by frame videotaped observations, seeing the effectiveness of the design model in action. Later on as the revision of the modules takes place, the results of adding new kinds of instructional tools or assessments to the modules will be examined along with more formal instructional outcomes.The focus will be on the innovative instructional processes and tools that are part of the creation of new instruction in school or other contexts. The process goes through periods of design and testing, with the processes and products of instruction being the the focus. Just as an engineer may come up with a design for a product that can be used in a variety of applications and tells us something fundamental about the nature of something, so too can instructional designers engage in a process that yields a process or product that can be applied to a variety of contexts and can tell us something fundamental about learning.

Although the notion of the learning sciences emerged before its publication, Stokes' (1997) book entitled *Pasteur's Quadrant* framed nicely what learning scientists were attempting to do. Dismissing the unidimensional "applied vs. pure" distinction in science, he proposed two dimensions: application-relevance and theory-mindedness. The traditional view of the continuum of applied to basic research limited theoretical advances to tightly controlled experimental research. What Stokes pointed out was that the applied versus basic continuum only dealt with one dimension, practical use. It did not address the other dimension of theoretical relevance. Pasteur used practical problems that were studied without some of the tight controls of the laboratory, yet his research had important implications for basic theories in microbiology. Learning scientists too, endeavor to do applied research that helps students and provides basic knowledge to the field of learning and instructional design. Stokes´ book reminded researchers that applied research could yield generalizeable findings that go beyond the specific context to a whole class of situations.

3. The emergence of the Learning sciences as a design science

Apart from its reliance on the multiple disciplines of cognitive science, and its willingness to consider context, the learning sciences are also noteworthy for their commitment to making education happen in authentic contexts. This commitment has several implications. First, the implementation requirement moves the learning sciences towards interventionist (and away from purely explanatory or predictive) goals. Second, because of the messiness of doing research in context, learning scientists are forced to consider methods that do not rely on tight experimental control. Hence, learning scientists have worked on developing design-based research methods.

To explore the role of design in the learning sciences, it helps to go back to the history of education as a discipline. While learning is pervasive throughout the history of the human race, formal teaching, especially as practiced in the classroom, is a more recent invention. Our current practice of universal, formal primary education, oriented towards basic literacies (linguistic and mathematical) is only a few centuries old. Lagemann (2000) describes how the twentieth century saw the consolidation of teaching as an academic discipline, and how newly founded colleges of education had to fight for academic legitimacy. Since the enlightenment, the academy has placed increasing importance on scientific forms of inquiry and knowledge (as contrasted with humanistic or craft-based forms). In the twentieth century, two schools of thought helped constitute these new colleges of education. One, led by John Dewey, emphasized pragmatic inquiry, philosophically informed but intimately tied to practice. Among his other achievements, Dewey (1896, 1929) both advanced the field of philosophy through his notions of pragmatism, and founded the first "lab school" in which teaching and learning concepts could be informed by practice. On the other hand, the psychologist E.L. Thorndike (1910) propounded a view of the field as a byproduct of psychological research in the behaviorist paradigm, with an emphasis on controlled experimentation, psychometrics, and animal studies. (To be fair, the differences between these two scholars were in emphasis; both recognized the importance of experimentation, and both recognized the importance of listening to practitioners, but their relative emphases concerning these activities were starkly different.) These two perspectives—education as a practice-informed profession, and education as a domain of psychology—competed throughout the twentieth century, but it is fair to say the psychological perspective dominated for much of the twentieth century. In many ways, the politics of the definition of the field centered on three key issues: the relationship between research and practice; the epistemology and fundamental assumptions of psychology as opposed to other social sciences; and the tension between modern, positivistic science as embodied in Thorndike's views and the postmodern perspective that somewhat parallel Dewey's perspective.

So given the diverse roots, what makes the learning sciences perspective different from the points of view that came before it? One element of the learning sciences is openness to multiple perspectives on learning. That openness is necessary because it takes multiple perspectives to understand the complex ecologies in which learning is situated. Just as traditional instructional designers work with stakeholders, learning scientists need practitioners and individuals who see the world from the perspective of sociology and anthropology as well as psychology. Thus, most often learning scientists operate as teams rather than individuals. Note, that even though learning scientists try to look to more than psychology when it comes to learning and instruction, they would welcome a psychological perspective as one window on learning. A second element that is important is a commitment to building solutions to the problems in teaching and learning in school ***and*** out of school. Learning scientists want to have an impact on learning and that means taking on the real world and its complexities. This often means studying the meaning of these complex contexts for learners at different stages of socialization into these contexts to understand how expertise is developed in real world. . Yet a third element is that knowledge of learning and instruction that is generalizable and meaningful can be acquired by studying the design process and is not just the province of experimental basic research done in laboratory settings. What this means for instructional designers is that they too can potentially contribute to the knowledgebase by documenting and reflecting on the design process, and using it as a means to collect information that can drive theory. Obviously not every project an instructional designer engages in will provide such insights, but documenting and reflecting on design projects in meaningful ways can lead to the development of new insights in to how people learn. A fourth element of the learning sciences perspective is to recognize the value of informal and non-traditional instructional contexts. As Bell, Lewenstein, Shouse, and Feder (2009) note, if one looks at schooling in the context of the learning someone does over a lifetime, it is clear that much more of someone's life span is spent outside of schools contexts in work and other situations. There is obviously value in studying learning in those contexts. Finally a fifth element is that learning scientists look to how new tools and artifacts created from the available technologies we have can be used to help facilitate learning. Just as an engineer might use a new type of material to create buildings that are better able to withstand hurricanes, learning scientists are interested in how the technologies that we have available can transform how we teach and learn. That means not only fitting technologies and tools into already existing structures, but also radically transforming those structures or even creating new ones (Collins & Halverson, 2009).

4. Findings and design implications of the learning sciences

In the prior sections, we have seen how the learning sciences capitalized on the multiple theories of learning arriving in psychology, drew on disciplines outside of psychology that better addressed issues of learning contexts, and maintained a 'hands on' stance towards designing interventions for both formal and informal learning contexts. In this section, we summarize some of the findings from this work over the last 30 years as they apply to the work of instructional designers.

We can divide the major findings and implications into three areas: research on thinking, research on learning processes, and research on learning environments.

4.1 Research on thinking and knowing

Research on thinking has helped fulfill the promise of cognitive psychology: uncovering the architecture of the mind and its workings. An excellent summary that holds up well despite its age is Newell and Simon's Unified Theories of Cognition (Newell, 1990).

One of the strongest findings has been that the mind, while incredibly flexible, appears to have specific limitations in how it can process information, relying on relatively specialized systems in the brain for functions such as vision, attention, memory, motor skills, language, and planning. Key findings have been the role of short-term and long-term memory, language, and skill in knowledge, including a rich idea of what it means to know something. Rather than assuming knowledge to be the ability to correctly recall facts, modern learning scientists distinguish between propositional knowledge, skills, and deeper conceptual knowledge. Additionally, research on individual differences shows that many individuals may learn the 'same' content differently, i.e., forming different representations of the ideas depending on their mental predilections. Useful instructional theories connect to this broader version of knowledge, including Bloom's Taxonomy, which highlights the difference between shallow and deeper forms of knowledge (L. W. Anderson, Krathwohl, & Bloom, 2001). Similarly, the theory of multiple intelligences reflects how different people may encode their understandings very differently based on sensory or learning preferences (Gardner, 1993).

Another key finding from the learning sciences is insight into the properties of expert thinking (Chi, Glaser, & Farr, 1988). Studies of chess players have shown that expert chess players not only know more about chess strategies, but their perceptions of chess boards are qualitatively different than novices--they can see problems in a way that leads to more economical thinking about solutions, and allows them to better remember the positions of pieces on a board quickly shown to them. Further studies have shown that, in contrast with novices, experts possess a number of strong mental resources in in every discipline studied. Experts can improvise to find solutions to problems using so-called 'weak methods', but are often efficient at using known solutions. Many of the skills needed to solve problems are 'automatized', meaning they can be executed easily without conscious thought (for instance, compare the mental effort required the first time to drive a car versus after years of driving). These automatic skills free up attention and memory for other parts of problem solving. In many cases, experts have not only knowledge, smart perception, and skills on their side, they also sometimes have 'mental models' which allow them to predict or simulate how things work in the world before attempting to solve problems. Finally, experts are often very good at monitoring their problem solving, and using reflection and planning to achieve their goals (Gentner & Stevens, 1983, Schoenfeld, 1983).

The primary implication of this research for instructional designers and teachers is to appreciate the complexity of expertise, and to deepen the ways knowledge is both shared and tested. An emphasis on factual recall is guaranteed to produce 'brittle' knowledge; whereas a focus on the development of instructional interventions that develop complex pattern recognition, build knowledge structures that focus on "big ideas," and supporting metacognitive processes are more likely to yield more durable learning.

4.2 Research on learning processes

Perhaps one of the biggest breakthroughs in the learning sciences was the examination of conceptual change (Vosniadou, 2008). Researchers found that constellations of memories, skills, perceptions, and ideas determined how people think and solve problems. Rather than starting as a blank slate, learners use their initial conceptions to think through problems. While refining that understanding or tweaking it is rather easy, much learning required deep reorganizations of ideas and ways of thinking about the world; for instance, distinguishing the scientific notions of heat and temperature requires sophisticated new ideas about energy, and suppressing the idea that things with high temperature necessarily have high heat energy (Carey, 1985). This complicated rethinking was not easy and required a great deal of mental energy on the part of learners, as well as careful support from the teachers. And, the shifts that took place often mirrored (or were mirrored by) shifts in language. (Driver, Leach, Millar, & Scott, 1996)

Advances were also made in understanding how literacies play a role in learning. On the psychological side, research helped to show the processes by which, for instance, students might decode a text, and make it correspond to their ideas about the world (Kintsch, 1998); or might try to coordinate an understanding of the world from multiple sources such as images and text (Mayer, 1993). In other domains, learners might develop understanding hand in hand with developing literacy of another kind, namely picking up the specialized representations used by experts in a domain, like the notation of mathematics or chemistry (Kozma, Russell, Jones, Marx, & Davis, 1996). Learning these literacies is more than psychologically decoding materials, it is also a social process of sensemaking and meaning making (Schoenfeld, 1991). Over time, learners who use representations socially will start to converge on a shared understanding that has not only formal meaning, but social meaning (Roschelle, 1992).

In many cases, this connection to real meaning can make or break learning. Researchers found that relevance and authenticity are crucial elements in this meaning-making process (The Cognition and Technology Group at Vanderbilt, 1990). Students who work on problems that (a) mean something to them personally and (b) are rich and complex enough to invoke real expertise, are far more likely to learn. Without authenticity, students might be motivated to learn within the confines of toy problems, but then would have difficulty applying their knowledge to other domains, the so-called transfer problem. (Bransford & Schwartz, 1999)

The instructional implications of this research on processes include focusing on relevant, authentic tasks for learners, and focusing on the difficult process of conceptual change. To foster conceptual change, learners need to deeply engage topics in ways that may radically shift their concepts, even while building on their existing conceptions. And the learning needs to take place through literacies and representations that allow the learners to make meaning individually and with others (Bransford, Pellegrino, & Donovan, 1999).

4.3 Research on learning environments

Understanding learning does not always mean knowing how to teach. The findings of the learning sciences in the 1980s and later often had to do with ways of understanding teaching in the new perspective of constructivism--either cognitive constructivism (focusing on the learner as performing a psychological learning process) or social constructivism (focusing on the learner as a participant in a sociocultural process of learning). Bransford et al. (1999) term this the 'learner-centered classroom', although increasingly as educators think about both formal and informal learning, 'learner-centered learning environments' might be more accurate.

Perhaps one of the more robust principles in the learning sciences is that one can structure supportive learning environments without resorting to direct instructionist transmission of information. The main metaphor used in the learning sciences to describe non-instructivist teaching is "scaffolding" (Wood, Bruner, & Ross, 1976). This term, like "constructivism", has come to mean many things in practice, but the common idea is that, like training wheels on a bicycle, the learner is supported in some way that provides room for exploration and self-directed learning, while still constraining the possibilities so as to minimize unproductive floundering.

Scaffolding takes many forms, ranging from computerized tools that support tasks, to activity structures, to larger social structures that support learning. For instance, an intelligent tutoring system might permit a learner to make only certain moves as he or she advances through the process of an algebra proof. The computer might use a model of human cognition to 'follow along with' the learner. When the computer senses that the learner is not following a reasonable problem-solving sequence, it can leap in with advice or simply limit the possible steps the learner might take. (Koedinger, 1998) Or, an online lab notebook might use a combination of hints, visualizations, and structured step-by-step supports to help students make sense of a desktop experiment. (Linn & Hsi, 2000) Or, a scaffolding scheme might not use technology at all. For instance, a technique called 'reciprocal teaching' is used in literacy education (Palincsar & Brown, 1984). Students take turns using strategies to comprehend text. Initially the teacher models these strategies, and over time students take the lead practicing them. Even such a simple technique was found by Palinscar and Brown (1984) to dramatically improve how well students learned reading skills. Finally, larger social structures can be used to support learning. One of the predominant theories in this area is "cognitive apprenticeship," with the idea that learners become 'apprentices' of a sort to experts, who model how experts think, coach learners as they practice problems (in context) with feedback, and fade their support and feedback over time to help learners become more autonomous (Collins, Brown, & Holum, 1991; Collins, Brown, & Newman, 1989). Rather than specifying a particular activity, cognitive apprenticeship spells out a relationship between novices and experts that allows transfer of expertise and supports learning. Such theories can be used to design social settings in which learners are able to construct an understanding. For instance, "computer-supported intentional learning environments" are a particular structure for classrooms, in which learners generate their own questions, then create, extend, and validate a shared knowledge repository (similar to how scholars conduct and share research) with the guidance of a teacher. A key aspect of such environments is that a certain sort of social context must be established, and the means for doing so is often not prespecified, but rather determined by the interaction between existing cultures and social contexts, and the educator's goals and relationships to those cultures and social contexts. (Tabak, 2004)

Conclusion

As stated earlier, the goal of this chapter has been to describe the Learning Sciences perspective and provide some insights that may prove useful to instructional designers. *How People Learn* (Bransford et al., 1999) summarizes this for designers and educators as the need for classrooms to be learner-centered, knowledge-centered, feedback- or assessment-centered, and community-centered. Sawyer (2006b) summarizes this as a focus on conceptual understanding, putting learning processes on par with teaching processes, aiming for authenticity, building on prior understanding, and providing opportunities for reflection.

For further reading, we recommend the journals *Journal of the Learning Sciences*, *International Journal of Computer-Supported Collaborative Learning*, *Cognition and Instruction*, and *Mind, Culture, and Activity*; the excellent volumes *How People Learn* (Bransford et al., 1999), the *Cambridge Handbook of the Learning Sciences* (Sawyer, 2006a), and *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser* (Resnick, 1989). For more on the relationship between the learning sciences and instructional design, we can recommend a special issue on the topic in the magazine *Educational Technology* (2004, vol. 44, no. 3).

In summary, research in the learning sciences has implications for instructional design by deepening our ideas about thinking and knowing; by illuminating the learning processes individuals go through; and by highlighting how learning environments can be designed to support learning. While this chapter cannot encompass everything, we have attempted to identify some major insights that may provide most useful.

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