TECHNOLOGY APPLICATIONS IN EDUCATION

A Learning View

Edited by

Harold F. O'Neil, Jr.
University of Southern California/CRESST

Ray S. Perez
Office of Naval Research

LEA LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS
2003 Mahwah, New Jersey London

Chapter 6

Theories of Learning and Their Application to Technology

Richard E. Mayer
University of California, Santa Barbara

Early in the 20th century, E. L. Thorndike, the world's first educational psychologist, envisioned a future in which educational practices in teaching would be guided by a psychological theory of learning (Mayer, in press-b). However, throughout the 20th century, psychologists and educators struggled to devise a theory of learning that is both educationally relevant and research based (Mayer, in press-a). At last, as the field of educational psychology enters its second century, it has become clear that much progress has been made in understanding how students learn in educationally relevant settings (Berliner & Calfee, 1996; Bransford, Brown, & Cocking, 1999; Bruer, 1993; Lambert & McCombs, 1998; Mayer, 1999c). The development of powerful instructional technologies—particularly based on computer and communication technologies—coupled with the rise of educationally relevant theories of learning offer the exciting opportunity to once again grapple with Thorndike's 100-year-old dream. This chapter is based on the premise that the way technology is used in education depends on the instructor's underlying conception of learning. This chapter proposes to examine current theories of how students learn and their implications for technology. The chapter begins with a introduction to constructivist theories of learning, examines four basic issues in the psychology of academic learning, examines three conceptions of learning, summarizes three varieties of constructivism, presents a cognitive constructivist model of technol-

ogy-based learning, and provides examples of how the theory can be applied to technology-based instruction.

A CONSTRUCTIVIST CONCEPTION OF LEARNING

Today's dominant theory of learning is constructivism—the idea that learning occurs when learners actively try to make sense of material presented to them. Learners engage in constructivist learning by actively and deeply processing the to-be-learned material in an attempt to understand it. Constructivist learning also can be called *knowledge construction*, because learners actively create their own knowledge, or *active learning*, because learners must apply and coordinate their own cognitive processes while learning (Mayer, 1999c). Constructivist learning has traditionally been referred to as *meaningful learning*, or learning by understanding, and can be distinguished from *rote learning*, or learning by memorizing (Wertheimer, 1959).

The conception of constructivist learning has important implications for instructional technology. Constructivist instruction is aimed at fostering and guiding constructivist learning, that is, it seeks to activate cognitive processing that leads to understanding. In short, constructivist instruction fosters constructive cognitive activity in the learner. Under this conception of learning, instructional technology should serve as a cognitive guide to help learners on authentic academic tasks—such as comprehending a text, solving a challenging mathematics problem, or conducting a scientific experiment.

It is important to recognize that constructivist instruction is not the same as hands-on learning or learning-by-doing, because behavioral activity is not the same as cognitive activity. As Ausubel (1968) and Mayer (1999c) pointed out, instruction that emphasizes behavioral activity (e.g., interactive games) can be designed in ways that either do or do not lead to cognitive activity, whereas instruction that does not emphasize behavioral activity (e.g., viewing a multimedia presentation) can be designed in ways that either do or do not lead to cognitive activity. For example, Mayer (in press-b) showed how the apparently passive task of viewing a multimedia presentation can lead to constructivist learning, whereas the apparently active task of answering questions can lead to rote learning. The crucial aspect of constructivist instruction is that it fosters appropriate cognitive processing in the learner rather than the level of behavioral activity that it requires.

Constructivist assessment focuses on the quality of learners' understanding rather than the quantity of knowledge they have acquired. The challenge of constructivist assessment is to develop techniques that assess students' ability to use what they have learned in new situations (i.e., transfer) in addition to their ability to remember what they have learned (i.e., retention).

137

ISSUES IN LEARNING, TEACHING, ASSESSMENT, AND TECHNOLOGY

How do students learn? How should teachers teach? How should learning be assessed? How should technology be used in education? In this section, four classic distinctions are examined: rote learning versus meaningful learning, curriculum-centered versus child-centered education, retention versus transfer assessments, and technology-centered versus learner-centered applications.

Learning by Memorizing Versus Learning by Understanding

Wertheimer (1959) provided an entertaining example of the distinction between two types of learning: learning by memorizing (rote learning) and learning by understanding (meaningful learning). In learning how to find the area of a parallelogram, one student learns to measure the height of the parallelogram, measure the base of the parallelogram, and multiply the height by the base using the formula, Area = Height × Base. According to Wertheimer, learning to blindly use a formula is an example of rote learning (learning by memorizing). The steps in the procedure are arbitrary to the learner and do not seem to fit with any existing knowledge. Wertheimer showed that students who learn by memorizing are able to solve problems that appear to be similar to those used during instruction (i.e., retention problems), but they are generally unable to solve problems that seem different even though the same principle applies (i.e., transfer problems).

In contrast, another student learns to find the area of a parallelogram by seeing that it is possible to cut off a triangle from one side of the parallelogram, connect it to the other side, and produce a rectangle. This student can use existing knowledge of how to find the area of a rectangle to compute the area of a parallelogram. According to Wertheimer, this student is learning by understanding, thereby showing structural insight into the relation between a parallelogram and a rectangle—namely, that a parallelogram is simply a rectangle in disguise. The steps in the solution procedure make sense because the learner can relate them to the familiar task of finding the area of a rectangle. Wertheimer showed that students who learn by understanding perform well both on retention and transfer problems.

Wertheimer's parallelogram example suggests that when the goal of instruction is retention, then learning by memorizing is an effective approach; but, when the goal of instruction is transfer, then learning by understanding is more likely to pay off. According to Wertheimer, learning by memorizing enables reproductive thinking (i.e., being able to reproduce what was taught), whereas learning by understanding enables productive thinking (i.e., being able to create a novel solution to a problem that has

not been seen before). Wertheimer's preference for meaningful over rote learning, first articulated more than 50 years ago, foreshadows the current interest in constructivist learning.

Curriculum-Centered Versus Child-Centered Education

How should teachers teach? Almost a century ago, Dewey (1902) made a classic distinction between curriculum-centered and child-centered approaches to education, which foreshadowed the current distinction between nonconstructivism and constructivist visions of education (Lambert & McCombs, 1998). In the curriculum-centered approach, the teacher begins with the material that needs to be covered and determines how best to help the learner master it. The curriculum-centered prescription, according to Dewey (1902, p. 8), is to "subdivide each topic into studies; each study into lessons; each lesson into specific facts and formulae. Let the child proceed step by step to master each one of these parts, and at last he will have covered the entire ground." What is learned consists of new skills and new pieces of information. The theory of learning underlying the curriculum-centered approach is that of the passive learner (Dewey, 1902, p. 8): "The child is simply the immature being who needs to be matured; he is the superficial being who is to be deepened. . . . It is his to receive, to accept." This view is consistent with behaviorism, which dominated the psychology of learning through the 1950s, and which is still the basis of many educational practices today (Burton, Moore, & Magliaro, 1996).

In contrast, in the child-centered approach, the teacher begins by understanding the characteristics of the learner and proceeds by creating opportunities for the learner to grow intellectually. The prescription for the child-centered approach, according to Dewey (1902, p. 9), is: "The child is the starting-point, the center, and the end. His development, his growth is the ideal." What is learned is a change in the learners' knowledge, including in how children think and control their own learning. The theory of learning underlying the child-centered approach is that of the active learner (Dewey, 1902, p. 9): "Learning is an active. It involves reaching out of the mind. It involves organic assimilation starting from within." This 100-year-old view is remarkably consistent with today's constructivist visions of learning and instruction, including learner-centered cognitive theories (Lambert & McCombs, 1998).

Assessment of Retention Versus Transfer

How should learning be assessed? The most thorough attempt to answer this question culminated in the publication of the *Taxonomy of Educational Objectives* (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Based on con-

ference participation from dozens of the top scholars over a 5-year period and input solicited from a thousand reviewers, the taxonomy's analysis of academic learning outcomes into categories has stood the test of time (L. W. Anderson & Sosniak, 1994). According to the authors, the taxonomy was "intended to provide for classification of the goals of our educational system" (Bloom et al., 1956, p. 1). At its most fundamental level, the taxonomy distinguishes between two broad goals—remembering material that was taught (i.e., which can be called *retention*) and being able to use it in new situations (i.e., which can be called *transfer*). Importantly, this fundamental distinction between retention and transfer has been retained in a revised version of the taxonomy (Anderson et al., 2001). This focus on transfer is consistent with constructivist principles.

One goal of instruction is remembering "either by recognition or recall of ideas, material, or phenomena" (Bloom et al., 1956, p. 62). A typical retention test item is: "A spaniel is a type of: (a) sword, (b) dog, (c) lace, (d) horse, (e) coin" (Bloom et al., 1956, p. 79). In a retrospective, Bloom (1994, p. 1) estimated that "as much as 90 percent of instructional time was spent at this level with very little time spent on the higher mental processes that would enable students to apply their knowledge."

In contrast, another goal of instruction is understanding. Bloom et al. (1956, p. 1) noted that "some teachers believe their students should really understand, others desire their students to internalize knowledge, still others want their students to grasp the core essence." Perhaps the greatest contribution of the taxonomy is the detailed presentation of multiple ways of assessing understanding, ranging from the ability to summarize the theme of a passage to being able to evaluate the effectiveness of a proposed problem solution. The taxonomy articulated a role for transfer as an important complement to retention:

> Although information or knowledge is recognized as an important outcome of learning, very few teachers would be satisfied to regard this as the primary or the sole outcome of instruction. What is needed is some evidence that the students can do something with their knowledge, that is, that they can apply the information to new situations and problems. (Bloom et al., 1956, p. 38)

The inclusion of understanding as a legitimate educational goal foreshadowed the constructivist emphasis on assessment of learner understanding.

Technology-Based Versus Learner-Based Applications

Two approaches to instructional design with educational technology are technology-based applications and learner-based applications (Mayer, 1999b). Technology-based applications begin with the capabilities of technology—usually cutting edge technology—and ask how these new technol-

ogy-supported capabilities can be incorporated into education. For example, a technology-centered application would be to figure out how to use virtual reality to improve the delivery of information to students in schools or how to insure all students have access to the World Wide Web. Unfortunately, technology-centered applications in education—ranging from motion pictures to radio to television to computer-assisted instruction—have generally failed to become integrated into the daily practice of schooling (Cuban, 1986) despite research indicating that some forms of technology-based instruction can improve student learning (Kulik, 1994; Schacter & Fagnano, 1999; Wenglinsky, 1998). In each case, strong claims were made for how a particular new technology would revolutionize education, but today schools are not heavily dependent on film, radio, TV, or computer-aided instruction (CAI). What went wrong? One answer is that the focus was on giving people access to the latest technology rather than on promoting human cognition through the aid of technology.

Learner-centered applications begin with a conception of how people learn and ask how technology can be used to foster human learning. In short, technology is seen as an aid to human learning, which Landauer (1995, p. 7) referred to as using computers as "augmentation" to the human mind. Similarly, Norman (1993, p. 12) argued that "technology . . . should complement human abilities, aid those activities for which we are poorly suited, and enhance and help develop those for which we are ideally suited." In short, technology can be used to expand cognitive capabilities, but to accomplish this goal instructional designers need a useful conception of how the human mind works.

In summary, constructivism emphasizes learning that is meaningful rather than rote, instruction that is child centered rather than curriculum centered, assessment based on transfer in addition to retention, and a learner-centered rather than a technology-centered approach to using educational technology. These four distinctions are summarized in Table 6.1.

THREE VIEWS OF HOW STUDENTS LEARN

During its 100-year history, educational psychology has devised three distinct visions of how students learn, reflecting what Mayer (1992a, 1996a,

TABLE 6.1
Four Issues in Education

Educational Area	*Educational Issue*
Learning	Learning by memorizing vs. learning by understanding
Teaching	Curriculum-centered vs. child-centered education
Assessment	Retention vs. transfer
Technology	Technology-centered vs. learner-centered applications