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THEORETICAL PERSPECTIVES INFLUENCING THE USE OF INFORMATION TECHNOLOGY IN TEACHING AND LEARNING

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Overview

In conceptualizing the nature of schooling, the common parlance is to describe a curriculum that contains content and is conveyed by a particular set of pedagogies. Its learning outcomes are evaluated by a suite of assessments; and – in the case of technology-based instruction – various aspects of content, pedagogy, and assessment are instantiated via computer tools and applications, digital media, and virtual environments. Other chapters in this handbook describe the relationships between information technology and curriculum, content, and assessment. This chapter discusses how various theories of learning and forms of pedagogy shape the technologies used to instantiate them, and how the evolution of computers and telecommunications is widening the range of instructional designs available.

The Relative Roles of Content, Pedagogy, Assessment, and Technology in Learning

An easy way to understand the role of information technology in helping students learn a curriculum composed of knowledge and skills, delivered via pedagogy, and evaluated through assessment is to see the tools, applications, media, and virtual environments used as instrumental. Information and communication technologies (ICT) aid with representing content, engaging learners, modeling skills, and assessing students' progress in a manner parallel to how a carpenter would use a saw, hammer, screwdriver, and wrench to help construct an artifact. The two key points in this analogy are (1) the tools make the job easier and (2) the result is of higher quality than possible without the tools.

J. Voogt, G. Knezek (eds.) *International Handbook of Information Technology in Primary and Secondary Education, 43–62*.

A simple idealized example that illustrates the use of ICT in helping students learn one portion of a curriculum is presented below:

> Ms. Smith was using a graphing calculator application on her handheld device to demonstrate how the graph for a particular type of function alters as various parts of the function (e.g., constants, variables, operators) change. Her graphing calculator was linked to a data projector so that all students in the class could observe what she was doing. In small teams, the students then practiced the same approach, using their individual calculators to alter the graphs of functions and discussing in the teams what they saw. Ms. Smith walked around the room watching the students, now using a different application on her handheld device to note, in terms of standardized rubrics, at which level of mathematical understanding each student was performing. From time to time, she intervened to remediate a misconception held by a student.

This illustration depicts the basic use of three technologies (a graphing calculator application and an assessment application on a handheld device, as well as a data projector) to aid students in learning a particular set of knowledge and skills (how the form of a particular type of function determines its graphical representation) using a variety of pedagogies (e.g., presentation, modeling, students' active construction of knowledge, collaborative learning) and conducting individualized, formative assessment. The teacher could attempt a similar form of instruction without these technologies, but this would require much greater effort and would likely result in lower learning gains and less student engagement.

Note that, even in this simple example, the exact demarcations between content, pedagogy, and assessment are difficult to establish. Is the graphing calculator's capability to rapidly display changes in a graph a representational aspect of content, or a pedagogical affordance? Is the handheld's capacity to allow facile, mobile input into a sophisticated assessment rubric an instructional facet of diagnostic remediation, or a form of summative evaluation? Content, pedagogy, and assessment are not discrete containers; and a particular technology may provide affordances that simultaneously influence more than one of these aspects of curriculum.

People who espouse particular forms of instruction have sought to develop technologies specifically instrumental for that type of pedagogy. For example, PowerPoint is an application developed to aid with the process of lecturing, a form of presentational/assimilative pedagogy. This tool is not intended to facilitate assessment and is deliberately designed to communicate a broad spectrum of content – although in fact PowerPoint is better at conveying some types of material (e.g., bullet points of information) than others (e.g., dynamic representations of changes in a system over time). An instructor can use PowerPoint well or poorly, with concomitant effects on the audience's engagement and learning.

What are the major types of instructional technologies that educators have created – or adapted – over the past few decades to serve as their toolbox? On what philosophies about teaching and instructional design are these pedagogical tools, applications, media, and environments based? For what types of learning has each proven effective?

The Current Spectrum of Instructional ICT

Many alternative conceptual frameworks exist for describing the relationships among learning theories, pedagogical strategies, instructional designs, and information and communication technologies. For some parts of its analysis, this chapter draws on an *Instructional Design Knowledge Base* developed by Dabbagh (2006) (http://classweb.gmu.edu/ndabbagh/Resources/IDKB/models_theories.htm). In the matrix that represents this conceptual framework, each school of thought posits basic principles and theories about learning; these inform the goals and models that school of thought has for instruction, which in turn influences the group's perspective on the design of pedagogical media. Many category systems are available to characterize contrasting positions about these issues. Drawing on Ertmer and Newby (1993) and Driscoll (2005), Dabbagh lists three competing schools of thought on how people learn: Objectivism/Behaviorism, Cognitivism/Pragmatism, and Constructivism/Interpretivism:

1. Objectivism posits that reality is external and is objective, and knowledge is gained through experiences. Behaviorists believe that, since learning is based on experience, instruction centers on manipulating environmental factors to create instructional events inculcating content and procedures in ways that alter students' behaviors.
2. Pragmatism posits that reality is mediated through cognitively developed representations, and knowledge is negotiated through experience and thinking. Cognitivists believe that, since learning involves both experience and thinking, instruction centers on helping learners develop interrelated, symbolic mental constructs that form the basis of knowledge and skills.
3. Interpretivism posits that reality is internal, and knowledge is constructed. Constructivists believe that, since learning involves constructing one's own knowledge, instruction centers on helping learners to actively invent individual meaning from experience.

Each school of thought is not a single unified theory, but rather a collection of theories distinct from each other, but loosely related by a common set of fundamental assumptions. This chapter draws on Dabbagh's framework, but provides a somewhat different perspective on each school of thought and its work, based on material from the National Research Council report, *How People Learn* (Bransford et al., 2000). Also, given the limits on space for a single chapter, the descriptions presented for each position are necessarily oversimplified.

Of course, educational ICT do not neatly cluster into discrete categories. Any given pedagogical tool, application, medium, or environment may incorporate perspectives from more than one of these intellectual positions. Imagine a multidimensional design space in which various specific instantiations of instructional technologies are represented; the dimensions reflect assumptions about learning, teaching, and instructional design. Some areas of that design space are more densely populated with clusters of ICT. These represent the schools of thought sketched below, but many outliers (not delineated in this chapter for reasons of space) are also present.

Behaviorist Instructional Technologies

As Dabbagh describes, Behaviorist theories of learning assume that knowledge is an absolute, reflecting universal truths about reality. Human behaviors, such as learning, are purposive, but are guided by unknowable inner states. Relationships between contextual instructional variables (stimuli) and observable, measurable student behaviors (responses) are the means to generate learning. Learning is indicated when a correct response follows the presentation of an instructional environmental stimulus. Instruction uses immediate consequences to reinforce behaviors to be learned and to repress incorrect responses to a pedagogical stimulus.

> As a basic example of this model of teaching and learning, a drill-and-skill instructional application is presenting a student with a series of single digit addition problems. Each time the student gets an answer correct, music plays and an entertaining animation is shown. Each time an incorrect answer is entered, a message is displayed, such as “Wrong; Try Again.” The problems are programmed to repeat occasionally, with problems previously answered incorrectly displayed more frequently. The instructional program keeps track of right and wrong answers, so the teacher can access information about the learner’s performance over time.

The psychological theories that underlie Behaviorist instruction initially were developed about a century ago and are associated with researchers such as Skinner (1950), Thorndyke (1913), and Watson (1913). Some Behaviorist researchers were willing to acknowledge the existence of inner states that might influence learning (Hull, 1943; Spence, 1942). Elaborate, modern instructional design strategies predominantly based on Behaviorist theories include Gagne (1988), Dick and Carey (1996), Smith and Ragan (1999), and Merrill (2002).

As Dabbagh indicates, in this school of thought, the purpose of education is for students to acquire skills of discrimination (recalling facts), generalization (defining and illustrating concepts), association (applying explanations), and chaining (automatically performing a specified procedure). The learner must know how to execute the proper response as well as the conditions under which the response is made. Knowledge and skills are transferred as learned behaviors; in classic Behaviorist instruction, internal mental processing is not considered as part of instructional design or assessment. Student motivation to achieve these goals is extrinsic, by associating pleasant stimuli with correct answers and neutral or even negative stimuli with incorrect responses.

Computer-assisted instruction (CAI) and learner management systems (LMS) are the two types of instructional technologies most closely associated with this school of thought, although many other ICT tools and applications utilize some aspects of Behaviorist design. Atkinson (1968) and Suppes (Suppes and Morningstar, 1968) were pioneers of computer-based instruction, as exemplified by the development of the PLATO and TICCIT CAI systems used in some schools in the 1970s. Instructional designers have since utilized this educational philosophy to create huge amounts of educational software, training students on content and skills in fields as disparate as reading, geography, history, mathematics, typing, science, and the operation of military equipment.

What the parts of these diverse subject areas taught by CAI have in common is an emphasis on factual knowledge and recipe-like procedures: material with a few correct ways of accomplishing tasks. So, for example, CAI can teach simple skills such as alternative algorithms for division, or contrasting ways to assemble and disassemble a gun, in which number of permissible variants is small and the end result is always the same. Factual knowledge, such as the year Columbus discovered America, is similar in its cognitive attributes: one right answer, basic mental processes primarily involving assimilation into memory. A contrasting illustration of knowledge and skills not well taught by CAI is learning how to write an evocative essay on “My Summer Vacation.” Behaviorist instruction can help with the spelling and grammar aspects of this task, but effective literary style is not reducible to a narrow range of “correct” rhetorical and narrative processes.

Learning management systems, prevalent in the 1990s and still operational today, involve more elaborate forms of Behaviorist instruction via Web-based media, with embedded, sometimes elaborate multimedia presentations; limited branching that provides alternative explanations for struggling students; multiple types of extrinsic engagement; and detailed recordkeeping that presents analytic summaries for teachers and parents. However, the underlying pedagogies in LMS closely resemble CAI.

Many research projects have evaluated the effectiveness of CAI as contrasted with conventional instruction, including meta-analyses that combine results across large numbers of studies. Typical of the latter is a recent meta-analysis of CAI in science education (Bayraktar, 2001): An overall effect size of 0.273 was calculated from 42 studies yielding 108 individual effect sizes, suggesting that a typical student moved from the 50th percentile to the 62nd percentile in science when CAI was used as compared to conventional classroom instruction. Effect sizes in the range of 0.15–0.3 are typical of meta-analyses for modern forms of CAI and LMS, if those instructional media are used for the type of content and skills for which they are best suited (Waxman et al., 2003).

CAI and LMS as pedagogical applications are limited both in what they can teach and in the types of engagement they offer to learners. As discussed above, only some forms of content and skills are effectively mastered by Behaviorist instructional methods, and much of modern curriculum lies outside the range of these pedagogical media. Also, learning involving low-level retention is typically not deeply interesting no matter what form of motivation is used; so many students quickly tire of music, animations, simple games, and other CAI forms of extrinsic reward, leading to apathy about mastering content and skills. This weakness is exacerbated by a fundamental assumption of Behaviorist instructional design that no complex knowledge or skill is learnable until the student has mastered every simple underlying subskill. This tenet leads to long initial sequences of low-level CAI in which students often lose sight of why they should care about learning the material, which may seem to them remote from the eventual goal-state of a more complex knowledge or skill with real-world utility.

Cognitivist Instructional Technologies

As Dabbagh describes, Cognitivist theories of learning assume that reality is objective, but mediated through symbolic mental constructs. Students learn through mastering building blocks of knowledge based on preexisting relationships among content and skills. Instructors organize and sequence these building blocks to facilitate optimal mental processing. Knowledge acquisition is a mental activity that also entails internal coding and structuring by the student. Successful learning is dependent not only on what the teacher or pedagogical medium presents, but also on what the student does to process this input, storing and retrieving information organized in memory.

> An example of this type of teaching and learning is the Andes Physics Tutoring System (VanLehn et al., 2005). Andes aids college students with physics homework problems. Its screen simultaneously presents each problem and provides specialized workspaces for learners to draw vectors and coordinate axes, define variables, and enter equations. These are actions that parallel what students do when solving physics problems with pencil and paper. However, unlike pencil and paper representations, Andes generates immediate feedback: Correct student entries are colored green; incorrect, red. Also unlike pencil and paper, variables are defined by filling out a dialogue box that forces students to precisely state the semantics of variables and vectors; for example, if students include an undefined variable in an Andes equation, the equation turns red and a message box pops up indicating which variable(s) are undefined. In addition, Andes includes a mathematics package: When students click on the button labeled "$x = ?$", Andes asks them for what variable they want to solve, then tries to solve the system of equations that the student has entered. Andes provides three kinds of help: It pops up an error message whenever a slip in problem solving is likely due to lack of attention rather than lack of knowledge, it enables students to ask for help in understanding why Andes has flagged what they have just entered as an error, and it enables learners who are confused to ask what they should do next. The help Andes provides is a sequence of increasingly specific hints. As the student solves a problem, Andes computes and displays a score that is a complex function of degree of correctness, number of hints, and good problem-solving strategies.
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> Contrasting this example to the Behaviorist illustration presented earlier provides a sense of the differences in pedagogical media developed by these two schools of thought.

The various psychological theories that underlie differing models within the general framework of Cognitivist instruction were developed by diverse groups during the second half of the twentieth century. Researchers whose theories were formative in developing this school of thought include Anderson (1993), Bruner (1960), Mayer (1977), Norman (1980), Newell and Simon (1972), and Palincsar and Brown (1984). Instructional design strategies based on Cognitivist theories often are designed to help students understand disciplinary knowledge (Case, 1992; Lee and Ashby, 2001; Hunt and Minstrell, 1994).

An example of an extensively developed, empirically grounded Cognitivist theory is Richard Mayer's work on multimedia learning. As summarized by Mayer and Moreno (1998):

> In multimedia learning, the learner engages in three important cognitive processes. The first cognitive progress, selecting, is applied to incoming verbal information to yield a text base and is applied to incoming visual information to yield an image base. The second cognitive process, organizing, is applied to the word base to create a verbally based model of the to-be-explained system and is applied to the image base to create a visually based model of the to-be-explained system. Finally, the third process, integrating, occurs when the learner builds connections between corresponding events (or states or parts) in the verbally based model and the visually based model.

Mayer's theory illustrates goals for instruction characteristic of the Cognitivist school of thought, which include (National Research Council, 2005):

- Providing a deep foundation of factual knowledge and procedural skills
- Linking facts, skills, and ideas via conceptual frameworks – organizing domain knowledge as experts in that field do, in ways that facilitate retrieval and application
- Helping students develop skills that involve improving their own thinking processes, such as setting their own learning goals and monitoring progress in reaching these

Student motivation to achieve these goals is determined by a variety of intrinsic and extrinsic factors, such as satisfaction from achievement, contributing to others, and challenge and curiosity (Pintrich and Schunk, 2001).

Although a wide variety of instructional technologies incorporate some principles from Cognitivism, intelligent tutoring systems (ITS) like Andes are veridical examples, illustrating pedagogical media based on this school of thought. As VanLehn (2006) describes, ITS have two loops by which the computer guides learning. The outer loop executes once for each task, where a task usually consists of solving a complex, multistep problem; its purpose is to select an appropriate task for the learner, given the student's past performance. The inner loop executes once for each step taken by the student in the solution of a task; its purpose is to provide feedback and hints on that specific step, as well as to assess the student's evolving competence and to update a model of what the student is judged to know at this point in the instructional sequence. That model of presumed student knowledge is eventually used by the outer loop to select a next task that is appropriate for the student.

The National Science Foundation (NSF)-funded Pittsburgh Science of Learning Center (http://www.learnlab.org/) is dedicated to designing and studying this type of instructional strategy. Core research questions this Center is currently addressing include:

1. *Cotraining*. When, how, and why do students' use of multiple inputs, representations, or strategies facilitate learning, by providing an avenue for "self-supervised" learning that goes beyond learning supported by teacher and peer feedback?

2. *Dialogue*. When, how, and why does classroom talk and tutorial dialog, whether by human or computer, promote robust learning?
3. *Refinement*. How do learners determine the causal connections between cues in the environment, their actions, and desired knowledge; and how can instructional support and feedback facilitate learners in making such connections?
4. *Fluency*. How does more isolated learning of knowledge components interact with learning within larger authentic performances, and how can instruction support such interactions to yield more fluent and robust learning?

Scholars disagree on how broad a range of knowledge and skills Cognitivist instructional technologies can teach. What the diverse subject areas now taught by pedagogical media like ITS have in common is well-defined content and skills, material with a few correct ways of accomplishing tasks. Current examples of ITS usage include mathematical reasoning, problem solving in scientific fields, learning a second language, and learning to read. The range of knowledge and procedures is somewhat similar to what is currently taught by Behaviorist instructional technologies, but more complex in detailed learning outcomes. Proponents of Cognitivist approaches believe that eventually ITS-like educational devices, coupled with human instructors, will teach most of the curriculum, including less-well-defined skills such as the rhetoric of writing an evocative essay. However, three decades of work toward this ambitious goal have yielded limited progress to date.

Some research studies have evaluated the effectiveness of ITS (illustrative of veridical Cognitivist instructional technologies). Illustrating typical results, Ainsworth and Grimshaw (2004) found that their REDEEM system for authoring intelligent tutors improves learning by about the same amount as nonexpert human tutors do compared to classroom teaching (REDEEM/CBT = 0.59 sigmas, human tutor = 0.4 (nonexpert) to 2.0 (expert)). Effect sizes for passage comprehension gains using an intelligent reading tutor, compared to silent reading, ranged from 0.48 to 0.66 (Mostow et al., 2003). VanLehn et al. (2005) reported that the overall effect sizes for the Andes intelligent tutoring system, compared to conventional methods of doing homework, ranged from 0.25 on the course final exam to 0.61 on the course hour exams; the latter were more representative in content and format of the knowledge and skills taught by Andes. Overall, these and similar findings about other ITS indicate a higher level of educational effectiveness than CAI or LMS instructional technologies.

Constructivist Instructional Technologies

As Dabbagh describes, Constructivist theories of learning assume that meaning is imposed by the individual rather than existing in the world independently. People construct new knowledge and understandings based on what they already know and believe, which is shaped by their developmental level, their prior experiences, and their sociocultural background and context. Knowledge is embedded in the setting in which it is used; learning involves mastering authentic tasks in meaningful, realistic situations. Learners build personal interpretations of reality based on experiences and interactions with others, creating novel and situation-specific understandings. Instruction can foster learning by providing rich, loosely structured experiences and guidance (such as apprenticeships, coaching, and mentoring) that encourage meaning-making without imposing a fixed set of knowledge and skills.

Constructivist pedagogical media span a wide range. An example that illustrates many aspects of this approach is the Jasper Woodbury mathematics curriculum (National Research Council, 2000, p. 208). Middle school students in math class view 15 min video adventures that embed mathematical reasoning problems in complex, engaging real-world situations. One episode depicts how architects work to solve community problems, such as designing safe places for children to play. This video ends with this challenge to spend the next week of class meetings designing a neighborhood playground:

> Narrator: Trenton Sand and Lumber is donating 32 cubic feet of sand for the sandbox and is sending over the wood and fine gravel. Christina and Marcus just have to let them know exactly how much they'll need. Lee's Fence Company is donating 280 feet of fence. Rodriguez Hardware is contributing a sliding surface, which they'll cut to any length, and swings for physically challenged children. The employees of Rodriguez want to get involved, so they're going to put up the fence and help build the playground equipment. And Christina and Marcus are getting their first jobs as architects, starting the same place Gloria did 20 years ago, designing a playground.

Students in the classroom help Christina and Marcus by designing swingsets, slides, and sandboxes; then building models of their playground. As they work through this problem, they confront various issues of arithmetic, geometry, measurement, and other subjects: How do you draw to scale? How do you measure angles? How much pea gravel do we need? What are the safety requirements?

Contrasting this example to the two schools of thought depicted earlier provides a sense of the differences in pedagogical media developed by these differing theories of learning and teaching. In particular, note that these students are learning simpler skills in the context of a complex task, in sharp contrast to Behaviorist instructional design.

The various social science theories that underlie differing models within the general framework of Constructivist instruction were developed by diverse groups over the past century. Researchers whose theories were formative in developing this school of thought include Bransford (Cognition and Technology Group at Vanderbilt – CTGV, 1993), Cobb et al. (1992), Dewey (1916), Johnson and Johnson (1989), Lave and Wenger (1991), Papert (1980), Piaget (1973), Rogoff (1990), Spiro et al. (1991), and Vygotsky (1978). Instructional design approaches based on Constructivist theories include anchored instruction (CTGV, 1993), case-based learning (Kolodner, 2001), cognitive flexibility theory (Spiro et al., 1991), collaborative learning (Barron, 2000), microworlds and simulations (White, 1993; White and Frederickson, 1998), mindtools (Jonassen, 2005), and situated learning in communities of practice (Lave and Wenger, 1991).

As Dabbagh indicates, this school of thought is characterized by goals for instruction that include:

– Instruction is a process of supporting knowledge construction rather than communicating knowledge.
– The role of the teacher is a guide, rather than an expert transferring knowledge to novices' "blank slates."
– Learning activities are authentic and center on learners' puzzlement as their faulty or incomplete knowledge and skills fail to predict what they are experiencing.
– Teachers encourage students in reflecting on experiences, seeking alternative viewpoints, and testing viability of ideas.

Student motivation to achieve these goals is determined by factors such as challenge, curiosity, choice, fantasy, and social recognition (Malone and Lepper, 1987; Pintrich and Schunk, 2001).

A broad spectrum of instructional technologies incorporates some principles from Constructivism. Many of these pedagogical media utilize tools and simulations to enable students to collect data via probes, to focus on complex skills while a tool does simple underlying tasks, to comprehend complicated ideas through visualizations that take advantage of the mind's ability to recognize patterns in sensory data, to test alternative models of reality via simulation, and to learn science, math, and technical skills through using programming to develop personally expressive representations such as digital art and movies (National Research Council, 2000). Providing examples that illustrate the full range of these features in various forms of Constructivist technologies is beyond the scope of this chapter.

Potentially, Constructivist approaches can teach a very broad spectrum of knowledge and skills, in contrast to current versions of Behaviorist and Cognitivist instructional designs. However, the efficiency of Constructivist learning technologies for material that these other two schools of thought can teach is questionable. Content and skills that are relatively invariant regardless of individual perspective (e.g., arithmetic operations, Newtonian physics) are learned more quickly when taught as "truths" than when found through exploration that, in extreme unguided forms, involves students slowly reinventing civilization (Kirschner et al., 2006). Proponents of Constructivism respond that their pedagogical media help students learn these types of knowledge with more depth and engagement and with greater meaning and transfer to life settings. Ultimately, as with all decisions about pedagogy, what is "best" depends on the instructional situation: the goals of the learning experience, the attributes of the students, the type of content, and the timeframe and resources available.

Identifying a suite of research studies that assess the power of all types of Constructivist pedagogical media is difficult. The range of these instructional technologies is quite broad, and the kinds of knowledge and skills they aid in learning are diverse and sophisticated, undercutting attempts to identify quantitative measures that span this range of teaching media. Projects such as the Jasper Woodbury series, described earlier, have extensive research results that document the effectiveness of this pedagogical approach. For example, compared to students receiving conventional mathematics instruction, students in Jasper classrooms showed greater effectiveness in solving complex problems and had more positive attitudes toward mathematics and complicated challenges (CTGV, 1992). (A detailed exposition of many types of research findings about Jasper is available in "The Jasper Project: Lessons in Curriculum, Instruction, Assessment, and Professional Development" (CTGV, 1997).)

A second Constructivist curriculum with substantial research findings is the ThinkerTools project by White and Frederickson (in press). Middle school students with no direct physics instruction taught with this approach did significantly better in solving a set of classic, qualitative force and motion problems than did high school students taught using traditional methods. Pupils at a young age displayed high level of interest and competence in "doing science." Students were capable of thinking at an abstract level both about the domain theories that they were developing and about the relationship of theory and evidence. High school and college students saw how models of a physical system may take many forms, each focusing on different objects and interactions as elementary units of analysis, and each employing a different type of reasoning process. Middle school students who were initially classified as low achieving (based on a standardized test used in the school districts) were able to approach the level of high-achieving students in the quality of their inquiry projects. The use of software advisors to model inquiry processes and general cognitive, social, and metacognitive processes – combined with the activity of having students take on the roles of advisors – was effective in improving students' inquiry skills and in developing their metacognitive theories and capabilities. Similar types of results showing high engagement and solid learning and metacognitive outcomes characterize many high-quality Constructivist curricula.

"Next-Generation" Pedagogical Media

As ICT continue to advance, new types of instructional opportunities are emerging. Another chapter in this handbook, "Emerging Technologies for Collaborative, Mediated, Immersive Learning" (Clarke et al., 2008), describes the evolution of the human computer interface:

- The familiar "world-to-the-desktop" interface provides access to distributed knowledge and expertise across space and time through networked media. Sitting at their laptop or workstation, students can access distant experts and archives, communicate with peers, and participate in mentoring relationships and virtual communities of practice. This interface provides the models for learning that now underlie most tools, applications, and media in K-12 education.
- Emerging *multiuser virtual environment (MUVE)* interfaces offer students an engaging "Alice in Wonderland" experience in which their digital emissaries in a graphical virtual context actively engage in experiences with the avatars of other

participants and with computerized agents. MUVEs provide rich environments in which participants interact with digital objects and tools, such as historical photographs or virtual microscopes. Moreover, this interface facilitates novel forms of communication among avatars, using media such as text chat and virtual gestures. This type of "mediated immersion" (pervasive experiences within a digitally enhanced context), intermediate in complexity between the real-world and paint-by-numbers exercises in K-12 classrooms, allows instructional designers to construct shared simulated experiences otherwise impossible in school settings.

– *Augmented reality (AR)* interfaces enable "ubiquitous computing" models. Students carrying mobile wireless devices through real-world contexts engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or an historic photograph offering a contrast with the present scene). This type of mediated immersion infuses digital resources throughout the real world, augmenting students' experiences and interactions.

That chapter depicts how the latter two interfaces enable immersion in rich simulated contexts, in which collaboration among learners is mediated and supported by a wide range of tools and applications. The reader is urged to scan that chapter for vignettes depicting how these new types of pedagogical media can accomplish this.

Early designs utilizing these immersive interfaces, such as the author's work on the River City MUVE (http://isites.harvard.edu/icb/icb.do?keyword=harp) and the Alien Contact! augmented reality (http://education.mit.edu/arworkshop/), illustrate that these pedagogical media can incorporate and intermingle all three schools of thought, bringing to bear whichever form of instruction is most appropriate as dictated by the immediate situation of the student. Preliminary research results are promising, particularly for the large proportion of students who now give up on themselves and school because they are not taught in ways compatible with their learning styles, strengths, and preferences (Dede, 2005). These immersive media also offer powerful laboratories for studying teaching and learning, because a detailed, time-stamped record of student actions and utterances is automatically collected (Ketelhut et al., 2007). This offers great potential for assessment, both from a research perspective and in terms of real-time, formative, diagnostic information that could help tailor instruction to individual needs.

Illustrative Historic Controversies About Technology and Pedagogy

As discussed above, the history of ICT documents waves of technologies (e.g., computer-assisted instruction, intelligent tutoring systems, tools, hypermedia, computer-supported collaborative learning, games) designed to empower particular forms of instruction in vogue at that time. Given decades of developing information technologies that aid various kinds of teaching and learning, what debates have emerged about media and pedagogy?

Is Learning via Media Intrinsically Inferior to Learning Face to Face?

Historically, technology-based education in general, and distance education and online learning in particular, have suffered from widespread misconceptions that these forms of learning are inferior to the traditional "gold standard" of face-to-face instruction (Dede, in press). Such false beliefs, which are contrary to considerable evidence across multiple research studies (Dede et al., 2002; Cavanaugh, 2001; Schacter, 2001), have retarded the adoption of powerful models for teaching based on sophisticated computers and telecommunications. Now, many levels of education are finally recognizing the value of ICT to aid learning, whether used as a complement to face-to-face instruction (termed hybrid, blended, or distributed approaches) or as a means of instruction without collocated personal presence (distance education).

The learning styles, strengths, and preferences for students of all ages are changing as their usage of media alters the processes by which people receive, create, and share knowledge (Dede, 2005). In the author's studies of "mediated learning" (Dede et al., 2002), many students reported that the use of asynchronous learning environments positively affected their participation and their individual cognitive processes for engaging with the material. Students also indicated that threaded discussions online often fostered better quality conversations than they had experienced in traditional classrooms. In addition, students generally indicated that the use of synchronous media enhanced their learning experience and complemented other delivery modes used in the course, including face to face. They indicated that synchronous virtual media helped them get to know classmates with whom they might not otherwise individually interact within a classroom setting; synchronous media also provided a clear advantage over asynchronous media in facilitating the work of small groups.

Overall, many students silent and passive in face-to-face settings "find their voices" in various forms of mediated interaction. Unfortunately, most instructors mistakenly assume that, because face to face is the form of learning/teaching with which they are most comfortable and adept, their students must be similar in their learning preferences and styles.

Do Media Influence Learning?

Historically, controversies have also arisen about the relationship between information technologies and pedagogy. A classic example of this is the extended debate between Richard Clark and Robert Kozma on the role of media (if any) in influencing learning. Beginning in the early 1980s, Clark wrote a series of widely read articles (e.g., 1983, 1994), arguing that media are "mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition." The core of Clark's thesis is that no single media attribute serves a unique cognitive effect for some learning task, because the same effect can be accomplished via various types of media, and therefore such attributes must be proxies for some other variables that are instrumental in learning gains. Clark (1994) further claimed that "media not only fail to influence learning, they are also not directly responsible for motivating learning," citing research evidence that students' beliefs about their chances to learn from any given media are different for different students and for the same students at different times.

During the early part of the 1990s, Kozma responded with a series of articles (e.g., 1991, 1994), taking a different position and fueling a lively scholarly debate. Kozma argued various studies showed that innovative applications of new media resulted in improved learning outcomes (e.g., the Jasper Woodbury curriculum described earlier). Clark was unconvinced, replying that such studies failed to control for instructional method and were therefore confounded; he argued that, without using a visual medium, teachers could present mathematics via engaging storylines based in real-world situations. Ultimately, Kozma (1994) suggested a reframing of the debate, "I believe that if we move from 'Do media influence learning?' to 'In what ways can we use the capabilities of media to influence learning for particular students, tasks, and situations?' we will both advance the development of our field and contribute to the restructuring of schools and the improvement of education and training" (p. 18).

Kozma's proposal to shift the debate to an instrumental point of view makes sense. We can imagine scholars of carpenter's tools arguing about whether a screwdriver can aid construction. One side of the debate posits that, because one can use the edge of a hammer's claw to clumsily turn a screw, the screwdriver does not influence construction, because another tool (or even a very strong fingernail) could do a poorer version of the same job. Certainly, how the screwdriver is helping construction is through the application of torque, and one can generate torque in a variety of ways. However, screwdrivers are specifically designed to facilitate torque, so from an instrumental point of view to argue that the screwdriver cannot influence construction seems an overly narrow perspective about cause and effect.

No instructional ICT is a technology comparable to fire, where one only has to stand near it to get a benefit from it. Knowledge does not intrinsically radiate from computers, infusing students with learning as fires infuse their onlookers with heat. However, media are able to aid various aspects of learning, such as visual representation, student engagement, and the collection of assessment data. Determining whether and how each instructional technology can best enhance some aspect of a particular pedagogy is as sensible instrumentally as developing tools that aid a carpenter's ability to construct artifacts. But are some media "off limits" because they are antithetical to learning and the objectives of education?

Can Some Media Undercut the Purposes of Education?

Beginning in 1980 with his book *Mindstorms*, Seymour Papert posited that some instructional technologies are detrimental to education because they encourage a pedagogy that is inimical to "true" learning. In *The Children's Machine* (1993), he argued that schooling "remains largely committed to the educational philosophy of the late nineteenth and early twentieth centuries" by attempting to "impose a single way of knowing on everyone." This type of instruction, according to Papert, is based on segregation by age, teachers who shape passive minds, an emphasis on reading as the "essential route to knowledge" through presentation/assimilation of information, and testing as the sole measure of success. He criticized schools for holding back learning through too much emphasis on abstract-formal knowledge, labeling students' knowledge as second-rate if it lacks precision.

Papert (1996) applied this philosophy about learning and teaching to make judgments about the value of various information technologies for education. He saw uses of ICT for CAI and ITS as flawed, because they emphasize Behaviorist and Cognitivist views of learning rather than what he termed a "constructionist" perspective on learning. In constructionism, a variant of Constructivist approaches, media of various types are used by learners to develop their own knowledge (rather than assimilating content and skills from a teacher) through constructing some external, shareable artifact (e.g., a computer program). Overall, Papert argued that some types of media are intrinsically better for learning and teaching, because instructionist (e.g., Behaviorist, Cognitivist) media control children's learning, while constructionist media empower students to take charge of their own education.

Given that people disagree both about what constitutes good pedagogy and about what are appropriate goals for schooling, that some scholars argue for certain types of instructional media and against others is not surprising. The core issue is whether there is just one preeminent way of learning/teaching for every student, for every subject, for all legitimate purposes of schooling. Ironically, in arguing that some types of instructional technology should be avoided because they impose a single way of knowing, Papert's perspective on learning, teaching, and media ends up itself narrowly oriented toward constructionism as the one right answer. He presents constructionism as if it were as perfect a solution for all learning as is presentational/assimilative pedagogy for the instructionist philosophers he labels as inflexible and dogmatic.

Reconceptualizing Media as Empowering Diversity in Learning

In fact, as the spectrum of theories about pedagogy discussed earlier suggests, learning is a human activity quite diverse in its manifestations from person to person. Consider three activities in which all humans engage: sleeping, eating, and bonding. One can arrange these on a continuum from simple to complex, with sleeping toward the simple end of the continuum, eating in the middle, and bonding on the complex side of this scale. People sleep in roughly similar ways; if one is designing hotel rooms as settings for sleep, while styles of décor and artifacts vary somewhat, everyone needs more or less the same conditions to foster slumber.

Eating is more diverse in nature. Individuals like to eat different foods and often seek out a range of quite disparate cuisines. People also vary considerably in the conditions under which they prefer to dine, as the broad spectrum of restaurant types attests. Bonding as a human activity is more complex still. People bond to pets, to sports teams, to individuals of the same gender and of the other gender. They bond sexually or platonically, to others similar or opposite in nature, for short or long periods of time, to a single partner or to large groups. Fostering bonding and understanding its nature are incredibly complicated activities.

Educational research strongly suggests that individual learning is as diverse and as complex as bonding, or certainly as eating. Yet theories of learning and philosophies about how to use ICT for instruction tend to treat learning like sleeping, as a simple activity relatively invariant across people, subject areas, and educational objectives. Current, widely used instructional technology applications have less variety in approach than a low-end fast-food restaurant.

Moreover, many educational designers and scholars seek the single best medium for learning, as if such a universal tool could exist. Some believe that one way of learning is universally optimal and therefore develop instructional ICT that embody that approach; others favor a slightly broader Swiss-Army-Knife design strategy that incorporates a few types of instruction into a single medium touted as a "silver bullet" for education's woes. As Larry Cuban documents in his book, *Oversold and Underused* (2001), in successive generations pundits have espoused as "magical" media the radio, the television, the computer, the Internet, and now laptops, gaming, blogging, and podcasting (to name just a few).

Of course, other gurus violently oppose each new type of instructional ICT, seeing that pedagogical approach as undercutting both the true objectives of education and the ways students can best learn. For example, at present, parents and politicians alike are decrying cell phones in schools and banning social networking technologies such as MySpace, despite widespread usage of equivalent tools in twenty-first century workplaces. Given all these claims and countercharges, it is unsurprising that the general public is confused about what types of ICT infrastructures – if any – are effective in education and about how much to invest in instructional technologies.

Investments in Instructional ICT Infrastructures

In light of this confusion, scholars such as Cuban (2001) argue that instructional ICT are far less useful than advocates claim and that other forms of educational investment may well produce better results in increasing student learning. Cuban documents that educational technologies divergent from teachers' current pedagogies are often unused, or utilized ineffectively. He also shows that advocates of ICT in education frequently make extravagant claims that prove hollow; and he expresses doubt that instructional technologies will ever have a transformative effect on learning, teaching, and schooling.

A weakness in this position is the tacit assumption, pervasive in most discussions about educational ICT, that instructional media are "one size fits all," with narrow types of tools (e.g., Logo programming, learning management systems) debunked to the chagrin of those who touted them. This instructional improvement strategy is the equivalent of asking a carpenter to build artifacts with only a screwdriver, or only a hammer – then concluding such tools are not useful because each in isolation has limited utility, as well as many weaknesses when broadly applied. In contrast, from an instrumental perspective, the history of tool making shows that the best strategy is to have simultaneously available a variety of specialized tools, rather than a single device that attempts to accomplish everything.

Further, all these pundits – pro and con – typically ignore the research literature on discipline-specific pedagogies (Shulman, 1986; Becher, 1987; Lampert, 2001). Numerous studies document that no optimal pedagogy – or instructional medium – is effective regardless of subject matter. As one example of research on subject-specific pedagogy, Garvin (2003) documents that the Harvard Law School, Business School, and Medical School have separately strongly influenced how their particular profession is taught, each by espousing and modeling sophisticated "case-method" instruction. Garvin's findings show that what each of these fields means by case-method pedagogy is quite different and that those dissimilarities are shaped by the particular content and skills professionals in that type of practice must master.

Thus, the nature of the content and skills to be learned shapes the type of instruction to use, just as the developmental level of the student influences what teaching methods will work well. No educational ICT is universally good; and the best way to invest in instructional technologies is an instrumental approach that analyzes the natures of the curriculum, students, and teachers to select the appropriate tools, applications, media, and environments.

Conclusion

Historic controversies about technology and pedagogy illustrate an apparently endless search for a universal method of teaching/learning that is best for all types of content, students, and instructional objectives. Parallel to this is a perennial belief that each new interactive medium is a "silver bullet" for solving education's problems, despite massive evidence from both research and experience that old content/pedagogy in new instructional containers does not produce major gains in effectiveness. To progress, the field of instructional design must recognize that learning is a human activity quite diverse in its manifestations from person to person, and even from day to day. The emphasis can then shift to developing pedagogical media that provide many alternative ways of teaching, which learners select as they engage in their educational experiences.

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