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Technology as Cognitive Tools:

Learners as Designers

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Technologies of instruction have traditionally been used as conveyors of information, communicators of knowledge, or tutors of students. Our field of educational communications is founded on the premise that communicating content to students will result in learning. In educational communications, information or intelligence (in many different forms) is encoded visually or verbally in the symbols systems employed by each technology. During the "instructional" process, learners perceive the messages encoded in the medium and sometime "interact" with the technology. Interaction is normally operationalized in terms of student input to the technology, which triggers some form of answer judging and response from the technology in the form of some previously encoded (canned) message. Technologies as conveyors of information have been used for centuries to "teach" students by presenting prescribed information to them which they are obligated to "learn."

Historically, educational communications have been developed and marketed to teachers by teams of educators, including instructional designers, subject matters specialists, media producers, and media managers. The instructional programs are designed using a variety of systematic instructional design models (Gagne, Briggs, & Wager, 1987; Dick & Carey, 1990) which have been advised by experimental research which is founded on very western notions of causality and determinism (more on this later). This systematic process embodies the very definition of our field (Ritchey & Seels, 1994). It contends that we can predict with accuracy the behavior and learning outcomes of organisms as complex as human learners. In this brief paper, I argue that these assumptions should be called into question, first on empirical grounds and second on philosophical grounds.

The first is easy: the overwhelming majority of unpublished research and the simple majority of published research in our field where we have used technology as conveyors or knowledge have produced "no significant differences" in learning as a result of their interventions. Why? Because we cannot predict with accuracy the behavior of complex organisms. Based on this empirical criterion alone, we should rethink the use of technology as mediators of learning.

The second reason is philosophical. We argue in a paper to be published in ***Educational Technology Research and Development*** (Jonnason, Campbell, & Davidson, 1994) that the process of learning is holistic. It cannot be understood by simply analyzing human responses to attributes of technologies that carry the messages to be learned. In fact, it is difficult, if not impossible, to isolate the effects of the affordances of technologies. Our instructional design models are grounded on two essential components of reality--objectivity and causality--both integral components of western consciousness. Objective reality is predicated on a number of assumptions, such as commonality of perception which supposedly enables us to observe and describe the physical world and to convey those descriptions to others as reality. In that article, we summarize thinking from quantum physics and chaos theory that argue against such assumptions (too lengthy to summarize in this short position paper).

Purpose

This short paper is about the application of technologies, primarily computers, as cognitive learning tools rather than as instructional media. I will argue that technologies, from the ecological perspective of Gibson (1979), afford the most meaningful thinking when used as tools. In the past, instructional designers have been invested with these tools for the purpose of "designing" instruction which, in effect, only constrained the learners. The only people who significantly benefit from the design process and the use of those tools were the designers, not the learners (Perkins , 1986). Therefore, I shall argue that we should take the tools away from the instructional designers and give them to the learners, as tools for knowledge construction rather than media of conveyance and knowledge acquisition. The process of building knowledge bases using these tools (a process that Papert refers to as constructionism) will engage the learners more and result in more meaningful and transferable knowledge in the learners. I argue that we should invest the power of the technologies in the learners. Power to the people, so to speak.

Computer technologies as cognitive tools represent a significant departure from traditional conceptions of technologies. In cognitive tools, information and intelligence is not encoded in the educational communications which are designed to efficiently transmit that knowledge to the learners. With cognitive tools, the traditional design and development processes are eliminated. Rather than using technologies by educational communications specialists to constrain the learners' learning processes through prescribed communications and interactions, the technologies are taken away from the specialists and given to the learner to use as media for representing and expressing what they know. Learners function as designers using the technology as tools for analyzing the world, accessing information, interpreting and organizing their personal knowledge, and representing what they know to others. Students demand definitions, so let me provide my conception of cognitive tools. What you believe them to be will depend upon your experiences with them.

Cognitive tools are generalizable computer tools that are intended to engage and facilitate cognitive processing--hence cognitive tools (Kommers, Jonassen, & Mayes, 1992). Cognitive tools are both mental and computational devices that support, guide, and extend the thinking processes of their users (Derry, 1990). They are knowledge construction and facilitation tools that can be applied to a variety of subject matter domains. I argue in the forthcoming book, ***Mindtools for Schools*** (Jonnasson, in press) that students cannot use these tools without thinking deeply about the content that they are learning, and second, if they choose to use these tools to help them learn, the tools will facilitate the learning process. Cognitive tools and learning environments that have been adapted or developed to function as intellectual partners with the learner in order to engage and facilitate critical thinking and higher order learning include (but are not necessarily limited to) databases, spreadsheets, semantic networks, expert systems, multimedia/hypermedia construction, computer conferencing, collaborative knowledge construction environments, and to a lesser degree computer programming and microworld learning environments. When students build knowledge bases with databases, expert systems, or semantic networking tools, they must analyze subject domains, develop mental models to represent them, and represent what they understand in terms of those models. It's hard work.

Rationales for Using Technology as Cognitive Tools

There are numerous reasons why using technology as cognitive tools rather than conveyors represents a better use of technologies.

Designers as Learners

The people who learn the most from the design and development of instructional materials are the designers. Jonassen, Wilson, Wang, and Grabinger (1993) reported this discovery while developing expert system advisors that were designed to supplant the thinking required by novice instructional designers. The process of articulating their knowledge about the domain of instructional design forced them to reflect on their knowledge in a new and meaningful way. Similar to the adage about the quickest way to learn about subject matter is to have to teach it, I argue that the process of designing and constructing materials that designers of educational communications perform enables designers to understand the subjects they are teaching much more deeply than the learners whose thinking will be constrained and controlled by the materials they are developing. Who should we be educating?

Learners as Designers

Students learn and retain the most from what Salomon calls "mindful" engagement. Some of our best thinking results when students try to represent what they know. Thinking is embedded in the tasks and functional requirements of cognitive tools. That is, cognitive tools require students to think mindfully in order to use the application to represent what they know. Just as electronics specialists cannot work effectively without a proper set of meters and tools to help them diagnose and repair electronic malfunctions, students cannot work effectively at thinking without access to a set of intellectual tools to help them assemble knowledge. Students should use technologies as tools, not as tutors or repositories of information.

Learners as Thinkers

Cognitive tools and environments activate cognitive learning strategies and critical thinking. They are computationally based tools that complement and extend the mind. They engage generative processing of information (Wittrock, 1974). In generative processing, deeper information processing results from activating appropriate mental models, using them to interpret new information, assimilating new information back into those models, reorganizing the models in light of the newly interpreted information, and then using those newly aggrandized models to explain, interpret, or infer new knowledge (Rumelhart & Norman,1978). Knowledge acquisition and integration, according to these definitions, is a constructive process, so when using cognitive tools, learners engage in knowledge construction rather than knowledge reproduction.

Cognitive tools actively engage learners in creation of knowledge that reflects their comprehension and conception of the information rather than focusing on the presentation of objective knowledge. They are learner controlled, not teacher or technology-driven. When students develop databases, for instance, they are constructing their own conceptualization of the organization of a content domain. Cognitive tools are not designed to reduce information processing, that is, make a task easier, as has been the goal of instructional design and most instructional technologies. They are not "fingertip" tools (Perkins, 1993) that learners use naturally and effortlessly. Rather cognitive tools provide an environment that often requires learners to think harder about the subject matter domain being studied while generating thoughts that would be impossible without the tool. They are cognitive reflection and amplification tools that help learners to construct their own realities using the constructs and processes in the environment on a new content domain.

Knowledge Construction, Not Reproduction

Learning theory is in the midst of another revolution (Jonassen, 1991). The new theory that is being used for representing the knowledge construction process is constructivism. How we construct knowledge depends upon what the learner already knows which depends on the kinds of experiences that the learner has had, how the learner has organized those experiences into knowledge structures, and the learner's beliefs that are used to interpret objects and events that s/he encounters in the world. Cognitive tools are tools for helping learners to organize and represent what they know. Constructivists claim that we construct our own reality through interpreting experiences in the world. Reality does not exist completely in the real world. The teacher cannot map his or her interpretation onto the learner, because they do not share a set of common experiences and interpretations. Rather, reality (or at least what we know and understand of reality) resides to some degree in the mind of each knower, who interprets the external world according to his or her own experiences, beliefs, and knowledge. If this were not the case, then every one of our experimental research studies would yield wildly significant differences. This does not mean that learners can only comprehend their own interpretation of reality. Learners are able to comprehend a variety of interpretations, including those delivered by technologies, and to use those in arriving at their own interpretations of the world. But the mind filters input from the world in making its interpretations. We each therefore conceive of the external world somewhat differently, based upon our unique set of experiences with the world and our beliefs about those experiences.

Constructivist models of instruction strive to create environments where learners actively participate in the environment in ways that are intended to help them construct their own knowledge, rather than having the teacher interpret the world and insure that students understand the world as they have told them. In constructivist environments, like cognitive tools, learners are actively engaged in interpreting the external world and reflecting on their interpretations. This is not "active" in the sense that learners actively listen and then mirror the one correct view of reality, but rather "active" in the sense that learners must participate and interact with the surrounding environment in order to create their own view of the subject.

Reflective Thinking

Norman (1993) distinguishes between two forms of thinking--experiential and reflective. Experiential thinking evolves from one's experiences with the world; it is reflexive and occurs automatically. You experience something in the world and react to it. Reflective thought, on the other hand, requires more careful deliberation. You encounter a situation, think about it, reflect on stored knowledge, make inferences about it, determine implications, and reason about it. Reflective thought is the careful, deliberate kind of thinking that helps us make sense out of what we have experienced and what we know. It usually requires external support, such as books, computers, or other people. Computers support reflective thinking, Norman contends, when they enable users to compose new knowledge by adding new representations, modifying old ones, and comparing the two. Those are the purposes of cognitive tools.

Learning WITH Technology

The primary distinction between traditional learning applications of technologies and their use as cognitive tools is best expressed by Salomon, Perkins, and Globerson (1991) as the effects OF technology versus the effects WITH computer technology. The former refers to the effects of computers on the learner, as if the learner has no input into the process. Learning WITH computers refers to learners entering into intellectual partnerships with the computer. Learning WITH cognitive tools refers to "the mindful engagement of learners in the tasks afforded by these tools and .... the possibility of qualitatively upgrading the performance of the joint system of learner plus technology." In other words, when students work WITH computer technology, instead of being controlled by it, they enhance the capabilities of the computer, and the computer enhances their thinking and learning. The results of an intellectual partnership with the computer is that the whole of learning becomes greater than the sum of its parts.

(Un)intelligent Tools

Educational communications too often try to do the thinking for learners, to act like tutors and guide the learning. These systems possess some degree of "intelligence" that they use to make instructional decisions about how much and what kind of instruction learners need. Derry and LaJoie (1993) argue that "the appropriate role for a computer system is not that of a teacher/expert, but rather, that of a mind-extension "cognitive tool" (p. 5). Cognitive tools are unintelligent tools, relying on the learner to provide the intelligence, not the computer. This means that planning, decision-making, and self-regulation of learning are the responsibility of the learner, not the computer. However, computer systems can serve as powerful catalysts for facilitating these skills assuming they are used in ways that promote reflection, discussion, and problem solving.

Distributing Cognitive Processing

Cognitive technologies are tools that may be provided by any medium and that help learners transcend the limitations of their minds, such as memory, thinking, or problem solving limitations (Pea, 1985). The most pervasive cognitive technology is language. Imagine trying to learn a complex process without the use of language. Language amplifies the thinking of the learner. Computers may also function as cognitive technologies for amplifying and reorganizing the way that learners think. When learners use computers as partners, they off-load some of the unproductive memorizing tasks to the computer, allowing the learner to think more productively. Perkins (1993) claims that learning does not result from a solitary, unsupported thinking by learners. So, our goal should be to allocate to the learners the cognitive responsibility for the processing they do best while we allocate to the technology the processing that it does best. For example, rather than focusing on micro-level decisions about message presentation characteristics of the computer screen, we should analyze what the computer is doing vis-a-vis the learner. Rather than using the limited capabilities of the computer to present information and judge learner input (neither of which computers do well) while asking learners to memorize information and later recall it (which computers do with far greater speed and accuracy than humans), we should assign cognitive responsibility to the part of the learning system that does it the best. Learners should be responsible for recognizing and judging patterns of information and then organizing it, while the computer system should perform calculations, store, and retrieve information. When cognitive tools function as intellectual partners, the performance of the learner is enhanced, leaving some "cognitive residue" in the learners which will likely transfer in situations where they encounter the tool again (Salomon, 1993).

Conclusion

Cognitive tools can be thought of as a set of tools that learners need in order to serve cognitive apprenticeships (cognitive apprenticeships are different from regular apprenticeships; see Collins, Brown, & Newman, 1989). They scaffold the all-important processes of articulation and reflection, which are the foundations of knowledge construction. They (gag, can I say it?) empower the learners to think more meaningfully and to assume ownership of their knowledge, rather than reproducing the teacher's. The major problem if we accept this conception of technologies is what to do with all of the instructional designers...

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