TEACHING FOR DEEP UNDERSTANDING

WHAT EVERY EDUCATOR SHOULD KNOW

KENNETH LEITHWOOD
PAT McADIE
NINA BASCIA
ANNE RODRIGUE

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Technology for Understanding

Marlene Scardamalia

> In this chapter, Marlene Scardamalia discusses determinants of understanding—prior knowledge, discourse, and effort to understand—and how information and communication technologies address these factors. She points out that technology is seldom used to promote deep understanding, but it could, and should be.
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> 1. Is the technology used in your school appropriate for teaching for deep understanding?
> 2. How does your current use of technology enhance or detract from teaching for understanding?

The learning sciences are a relatively new field, located at the intersection of learning research and technology development. Problems of understanding have been a focus of research in the learning sciences over the past quarter-century. Much of this research has dealt with problems of understanding in particular subject areas, but learning science research has also yielded general findings relevant to achieving understanding in all areas. The following three factors deserve special attention because they are often neglected in both traditional and constructivist approaches to teaching for understanding:

1. **Prior knowledge**—Prior knowledge is a major determinant—frequently the major determinant—of what will be understood and also of how it will be understood. Prior knowledge provides the framework, schema, or mental model within which new information is interpreted (Anderson & Pearson, 1984). Misconceptions typically arise when prior knowledge differs in a fundamental way from the intended knowledge.

2. **Discourse**—Experiments, observations, reading, and various kinds of first-hand experience yield information. The converting of such information into knowledge does not take place automatically. It requires reflection, which in turn depends preeminently on discourse (Brown & Campione, 1996). Discourse that is limited to the sharing of information and opinions does not serve this reflective purpose.

3. **Effort to understand**—Activities such as experimentation and use of manipulatives frequently fail in many students to produce the desired understanding. Further investigation shows that those who achieved it were actively trying to understand whereas those who failed to grasp the intended principles focused only on the activity itself (Bereiter & Scardamalia, 1989).

Information and communication technology (ICT) approaches to teaching for understanding differ considerably in the ways they deal with or fail to deal with these three factors.

ICT DESIGNED TO PROMOTE UNDERSTANDING

Three distinct lines of ICT development have implications for increasing depth of understanding:

1. **Computer-assisted instruction (CAI)**. The teaching of concepts and principles has been a major interest of instructional scientists working in this field. Designers of CAI aim to optimize presentation sequences for information, thus enabling students to master designated concepts.
2. **Simulations, games, laboratory tools, and other hands-on resources**. ICT has considerably expanded the possibilities of "learning by doing" in the classroom.
3. **Supports for explanation, argument, and knowledge building dialogue**. These range from the ubiquitous threaded discussion forums to software environments expressly designed for sustained work with ideas.

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The most commonly used ICT in schools, however, is not any of these. It is productivity software—word processors, presentation software, spread sheets, facilities for producing Web pages, and so forth—designed for business use. An international survey showed this to be the case worldwide, even in schools identified as innovative (Kozma, 2003). Although there are special versions of productivity software for schools, they are generally simplifications designed for ease of use but otherwise similar to the business applications. One might expect such technology to be neutral as regards learning with understanding, but in fact, there are growing complaints that it encourages attention to presentational style rather than content, thus militating against pursuit of understanding. (Such complaints are arising even in the business literature: Executives are accused of lavishing too much effort on flashy presentations and not enough on the quality of information and ideas.)

Another widely used type of ICT that is ostensibly neutral with regard to understanding is course delivery systems. Developed for higher education but now making their way into schools, course delivery systems are essentially tools for putting conventional courses online. Hence, they provide for electronic reading lists; online lectures, readings, and other instructional "objects"; and electronic submission of course assignments, quizzes, discussions, and e-mail communication between instructor and students. As in conventional courses, teaching for understanding is the responsibility of the instructor or course leader and depends on the kind of information delivered and the kinds of activity promoted. Far from being neutral with regard to pedagogy, course delivery systems transfer traditional courses to an online format, along with their bias toward information transmission rather than constructivist educational approaches.

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The remainder of this chapter concerns itself with the three ICT approaches that are directly aimed at teaching for deeper understanding. In all of these cases, it is difficult to make general evaluative statements because quality ranges from low to high. Also, there is so much diversity within each type that it is difficult to say what constitutes quality. We can, however, point out some of the less obvious strengths and weaknesses of each type of resource and offer suggestions about how ICT may be used in efforts to foster deep understanding.

COMPUTER-ASSISTED INSTRUCTION

The oldest of the three approaches, CAI, varies from simple drill-and-practice software to sophisticated applications that use artificial intelligence to gauge the state of the learner's knowledge and to select strategic moves to enhance it. Most of the CAI used in schools is of the drill-and-practice variety, which makes no pretense of teaching for understanding. This is true even of most programs that purport to teach reading comprehension or mathematical problem solving. In effect, they merely provide drill and practice on comprehension or problem-solving test items. Nevertheless, instructional design theory, the scientific discipline underlying CAI, has been much concerned with teaching for understanding, and there are CAI programs in science,

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> 2. Discourse that supports sustained inquiry and idea improvement
> 3. Web search tools that zero in on explanatory rather than merely topical information
> 4. Knowledge building environments that provide a coherent framework for pursuit of understanding
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> Such technologies exist but are underused.

mathematics, language, and social studies that teach concepts and principles (Reigeluth, 1999).

With regard to the three learning science principles of teaching for understanding, CAI typically pays little attention to students' prior knowledge or misconceptions. However, CAI designers usually employ some form of task analysis to identify prerequisite knowledge, and they try to ensure that the prerequisites are in place before a next step in learning is introduced. As regards effort, CAI tends to focus students' efforts on getting correct answers rather than on understanding. To the extent that getting the right answer is an indicator of understanding (and in well-constructed CAI programs this is the case), the program may be said to enlist students' efforts in ways that promote understanding. Still, this is not the same as getting students to try to understand or to adopt understanding as a goal. The weakest aspect of even the strongest CAI programs, however, is that there is little or no opportunity for student discourse. The programs are so structured as to provide students with little about which to discourse.

Simulations, Games, Laboratory Instruments

This category covers a wide range and includes some of the most ingenious and highly developed software to be found in schools. The common characteristic of these programs is that they generate information in response to actions by the learners. Thus, in a broad sense, they are tools for inquiry. A distinction should be made, however, between ICT that provides direct contact with "nature" and ICT that provides contact only with simulations. Examples of the former are computer-based laboratory instruments, such as pH meters, and Lego Logo. Simulations are ubiquitous. Hundreds of small simulations, usually in the form of Java applets, are available on the Web. There are also more powerful simulations and simulation-building tools, which permit active exploration and experimentation. It is well to keep in mind, however, that in using such applications, students are not interacting with the real world; they are interacting with a theory about the real world. This has both virtues and drawbacks. A simulation based on Newtonian mechanics or Mendelian genetics is likely to represent a simplified world free of the complications that affect motion and inheritance in nature. This makes the theoretical principles easier to grasp, but it also means that how deeply the students can go into understanding motion or inheritance is limited to what the simplified world embodies.

Technology to Support Discourse

Many different kinds of software provide facilities for discussion, but this tends to be the weakest part of the application. Often the discussion facility is tacked onto or is a modification of an application designed for some other purpose: for conventional course delivery, for e-mail, for document management, or for virtual laboratory work. The facility provides for posting messages, usually in chronological order, and for responding to or commenting on these messages. But often there is no provision for commenting on comments, thereby limiting dialogue to two steps. Better developed applications provide for "threaded" discourse, which would better be called branching discourse because what it amounts to is comments on comments, comments on comments on comments, and so on to an indefinite number of branches. The result, however, is hierarchical decomposition. Students can work down from an idea to details, but they cannot work up from the idea to a higher level, more inclusive idea that would subsume existing branches. Neither is it possible to connect an idea in one thread to an idea in another thread, except by textual reference. Thus, the software militates against the kind of synthesizing, connecting, and intertextuality that are essential for the collaborative pursuit of deeper understanding. Such technology is well suited to the uses one finds in the typical Web forum—to question-answer and opinion-response dialogue. But it is radically unsuited to anything that could be called knowledge construction or idea development.

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A facility that provides for superordination (creating a higher level node) as well as subordination and also for linking horizontally (such as across threads) is entirely feasible. In fact, Knowledge Forum®, technology created at OISE/UT, provides such facilities and more to encourage depth of learning. Superordination is provided by "rise-above" notes, which subsume a set of existing notes within a synthesizing or summarizing note. Any note may be linked to any other note. An even more versatile means of representing higher level organizations of ideas is the "view." A view provides a graphical background that can display categories and category relationships, with individual and linked notes appropriately placed on the screen in relation to this background. In particular, a view can represent graphically the big ideas that frame an inquiry. Views can be linked to other views and can be subsumed by still higher level views. A particular note can appear in more than one view. Thus, wherever students are in a Knowledge Forum database, they can move up to create a higher level object, down to create a subordinate one, or sideways to connect one note or view to any other note or view.

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The World Wide Web and the Pursuit of Understanding

The World Wide Web has been heralded as a vast information resource, enabling students to pursue inquiries independently and in greater depth than was possible when they had to rely on local print resources. There is converging evidence, however, that use of the Web encourages the gathering of miscellaneous facts about a topic rather than pursuit of deeper understanding (Moss, 2000). This should not be surprising, given the nature of popular search engines. They are good for zeroing in on a topic and finding the most popular documents related to the topic, but not for finding answers to "why" questions.

Problem-driven as opposed to topic-driven search is a theoretical possibility, but perhaps not an economically realistic one. For the present, teachers can refrain from assignments and projects that encourage topical fact-gathering. This means abandoning the time-honored research report or project, with its emphasis on collecting, organizing, and creating attractive displays of topical information. The alternative is genuine inquiry, driven by problems of understanding. When such inquiry is pursued collaboratively, students can share relevant findings from the Web, thus partly overcoming the limitations of Web searches. They can also share words and phrases that have proved useful to enter into Web search strings.

Toward More Sophisticated Software

Knowledge building (Scardamalia & Bereiter, 2003) is a process of sustained idea improvement fostered by communities, in which participants take responsibility for the advancement of community knowledge. Learning scientists, along with historians, philosophers of science, and other knowledge scientists, have studied the history of thought and its evolution, practices of novices and experts, and cultures of innovation. From this work, we know that deep understanding requires sustained idea improvement and that the knowledge building trajectory starts with the early, natural ability to play with ideas and extends to the not-so-natural and relatively rare intentional processes that serve to continually improve ideas.

> Deep understanding results when ideas become objects of inquiry and the discourse that surrounds them leads to their continual improvement.

Our expanded understanding of knowledge building has opened the possibility of knowledgeware that renders the hidden dynamics of sustained idea improvement transparent and embeds them in daily interaction between people and ideas. The surest way to support deep understanding is to make it integral to the day-to-day workings of classrooms. A new class of software, known as Knowledge Building Environments (KBEs), is designed to enable this (Scardamalia, 2003a).

In line with this requirement, KBEs make it possible to import any digital representation of an idea from any application into a community workspace. In the community workspace, the idea is built on, annotated, referenced, integrated into a higher order representation, reconstructed in multiple views, and so forth. KBEs additionally support users in generating and contributing ideas. All media types (text, video, graphic, scanned image, audio, and so forth) can become part of this community-constructed resource. As ideas are contributed, advances by one member precipitate further advances, at both the individual and group levels, so there is a continual movement beyond current understanding.

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The design of KBEs is a major engineering task. Knowledge Forum, the environment mentioned above, is the original KBE; it currently provides the basic means for bringing work with all digital media into the knowledge building process. Users can import screen shots and various kinds of application output into Knowledge Forum notes and launch applications from within the environment, providing a basic means for bringing all kinds of work with digital media into the knowledge building process. And participants' self-generated ideas become objects of inquiry, to be explored and improved along with ideas created by others, bringing different worlds of knowledge work together into a coherent framework. It is thus possible to integrate the kinds of applications listed above, adding a meta-layer in which the outputs from these applications become objects of inquiry in the service of larger knowledge building objectives.

Toward a More Sophisticated Market

Educational software could be much better than it is. The research is there and the prototypes are there to produce technology that supports rather than undermines the pursuit of deeper understanding. What is missing is market demand. The most prevalent use of ICT in elementary classrooms is to provide digital versions of what used to be done with old magazines, scissors, and library paste. One kind of cut-and-paste has been replaced by another. It is absurd to talk about an educational revolution when that is the reality.

To serve purposes of deepening understanding, schools need (1) simulations that allow for deeper exploration, (2) discourse that supports sustained inquiry and idea improvement, (3) Web search tools that zero in on explanatory rather than merely topical information, and (4) KBEs that provide a coherent framework for use of the preceding technologies in pursuit of understanding. All of this can happen, but it will not happen until the school ICT market starts to demand it.