What Research on Learning Tells Us About Teaching

Three insights — that there are multiple forms of learning, that students must build on prior knowledge, and that learning is a social act — have important implications for teachers.

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What's new in the research on learning that affects teaching? Over the last decade, we've seen a plethora of new terms, approaches to research, and evidence on the nature of learning. *Authentic activity, apprenticeship learning, case-based research, conceptual change, constructivism, distributed knowledge, narrative/episodic knowledge structure,* and *socially shared cognition* are terms that abound in the literature. Three constructs are fundamental to these new terms: (1) the multiple forms of knowledge, (2) the role of prior knowledge, and (3) the social nature of knowledge and its acquisition.

Multiple Kinds of Knowledge

The first finding is that there are both different kinds and amounts of knowledge. This does not simply mean, as it did with Bloom's taxonomy, that there are different levels or depths of knowledge. It means that there are both knowledge of actions and skills and knowledge of concepts and principles. The student's task is to connect strategic action knowledge with specific content knowledge.

When we examine the kinds of information and generative power we expect students to develop, we realize that knowledge varies both *within* and *across* subject-matter areas. Knowledge varies *across* subject matter because subjects have different arrangements of facts, concepts, notations, and patterns of reasoning. Knowledge varies *within* subjects because some academic subjects have elaborate and importantly constraining notational systems. A map is not like a musical score, which is not like the equation for a function, which in turn differs from an evolutionary tree.

Other disciplines have intricately layered ways of developing arguments and handling evidence (for example, history and literature), while still others require documentation of procedures in highly codified ways (chemistry and biology). In organic chemistry, the facts and rich combination of taxonomy, algebra, and geometry form a conceptual basis of knowledge and a powerful clue as to the actions that a chemistry student performs. That knowledge simply does not look or feel like the knowledge necessary to form an historical argument or to construct an explanation in biology.

In addition to knowledge of parts of

In classrooms that reflect learning's social nature, students are active constructors of knowledge. Shown here are students from Douglas County School District's Higher Literacy Project.

a subject, knowing what you know (metaknowledge) and how well you know it is also important. As research has pointed out, skilled performers within a knowledge domain have extensive awareness of their own knowledge. A competent reader is aware of character, plot, and prediction. A competent science student constantly constructs personal explanations of new material, forcing it to be consistent with the fundamental design of the prior information.

These multiple forms of knowledge render learning and performing tasks more complex. Consider a social studies class discussing why in the move westward of American pioneers, the Midwest was settled after the West Coast. One explanation might include the following arguments: News of the gold rush in California prompted the pioneers to bypass this territory. Further, severe conditions in the Midwest — for example, extreme weather conditions and hostile interactions with Native Americans — made it appear undesirable for settlement. The task for students is to construct an explanation of this pattern of settlement that synthesizes various kinds of information. To do so, students need to understand the principles of forming an explanation in social studies; the history of the time and the geography of the United States; be able to use the representational systems of maps; and monitor their own oral discussions as they produce the explanation.

This example points up the particular use of different kinds of knowledge in performing a relatively simple and common school activity. The existence of different kinds of knowledge has implications for both teaching and learning. Any one of these types or forms of knowledge can be taught and learned in a way that results in inert, disconnected information rather than principled, generative ideas. Simply saying that different disciplines have different notational systems, rules of evidence, or deductive properties does not give teachers or students much to go on in terms of issues of sequence, complexity, or active experiences for learning.

In addition to knowledge of a subject, knowing what you know (metaknowledge) and how well you know it is important.

One pedagogical problem is how to transform what has traditionally been regarded as a linear process of knowledge acquisition into a multifaceted system. Such a system must include the content of a field such as history or mathematics (for example, the gradual elimination of slavery or the number system) and the actions of the field (explaining and interpreting, or posing problems).

Another difficulty is how to help develop in students a focus on deeply principled aspects of knowledge as opposed to shallower ones. Clearly, teaching the underlying principles alone does not improve performance, but, equally clearly, performance proficiency does not produce conceptual understanding. One suggestion is to consistently teach these different kinds of knowledge together in action, explicitly acknowledging how the different forms of knowledge work together. The pieces of needed knowledge are seen as working together when the acts of problem posing, solution, and learning are public and shared.

Role of Prior Knowledge

What kinds and amounts of knowledge one has before encountering a given topic in a discipline affect how one constructs meaning. The impact of prior knowledge is not a matter of "readiness," component skills, or exhaustiveness; it is an issue of depth, interconnectedness, and access. It includes all of the kinds of knowledge described above and their interrelationships — and is the source of both conceptions and misconceptions. Learning outcomes are determined jointly by what was known before and by the content of the instruction.

Prior knowledge also dramatically influences the processing of new information. It affects how students make sense of instruction both in a facilitative sense and in a dysfunctional sense. For example, how we read a text is influenced by what we expect (from previous experience) to find there and how that material is parsed. Thus, a headline such as *Vikings Cream Dolphins* has a different meaning depending on whether we are thinking about the eating habits of ancient seafarers or about U.S. football teams. Similarly, if one believes that light emanates from an object (as many naive science students seem to believe), then science textbook diagrams such as those showing dotted lines between the human eye and a perceived object have a different meaning and interpretation than they would if one believed objects are seen because of reflected light.

Robert Kalman

Knowledge is a complex network of ideas, facts, principles, actions, and scenes; therefore, prior knowledge is more than a building-block of information. It can facilitate, inhibit, or transform a common learning task. Consider the common use of base-ten blocks (Dienes blocks) in teaching arithmetic. Dienes blocks are often used to provide a concrete representation of "regrouping" in addition. Students work carefully through several different mathematical tasks in which they trade Dienes blocks of different values (for example, 9 single blocks and 7 single blocks may be traded for 1 tens block and 6 ones blocks). When students then encounter the use of Dienes blocks in an introductory lesson for another piece of mathematics, such as the regrouping necessary in some subtraction problems, students who have prior knowledge of the actions and meanings of the blocks are no doubt in better shape than those who do not have this prior knowledge and who must learn both the meaning of the concrete representation and the arithmetic simultaneously.

Suppose, on the other hand, a student who has worked extensively with these base-ten blocks in the whole number domain is asked to use them for decimal fractions. Although this is often recommended, it can be problematic. The switch from the large cube's familiar representational meaning of one thousand (with 10 small cubes on each row of each face and 100 cubes on a face) to a new meaning of one whole is possibly confusing. When the large thousand cube represents thousandths, its construction suggests that decimals can only go down to one thousandths. Further, the very thing that makes decimals different from whole numbers, the shift from the infinite to the infinitesimal, is blurred. In this case, the prior knowledge of the representational system — the Dienes blocks — could inhibit the learning of the new material.

Finally, consider a student who has no knowledge of either the blocks or the rules of working with them. For that student, demonstrations with the blocks and their trading of tens for ones and hundreds for tens becomes an object for learning in and of itself. Further, learning the analogical mapping between the blocks and the symbolic number system becomes a second task, requiring serious revising of the learner's initial understanding. Subtracting with blocks involves no place value, in the sense of right or left placement; the value is in the blocks themselves. Using the blocks for subtraction with regrouping requires a "bank" to which one can go for denominational exchanges.

Both of these circumstances are reversed when a student is working in the symbolic number system. The student who is to use the blocks to learn subtraction with regrouping and to gain a deeper insight into mathematical concepts faces a complex task if both representational systems are used. The student needs to understand that the use of the blocks is analogical, that the task is not simply to use the blocks but to use them to understand the symbol system. Further, the student needs to realize that some explicit parts of each "world" connect; this is representational knowledge. Finally, he or she needs to know that results in each world need to correspond in their outcomes — the "answers" should be the same. This is what is meant by action and epistemic knowledge.

For each new learning situation, the student may have one or more of these pieces in place. The teacher needs to know not just how much is in place but in what configuration. Under traditional conceptions of teaching, gaining this knowledge for every student would be difficult, even impossible. However, as is discussed in the next section, there are some proposed alternatives.

The task for students is to continuously connect their own prior knowledge with new information. A teacher may easily, and a textbook by necessity does, enter a topic in a place that is somewhere in the middle of the student's existing knowledge, which may be robust and correct, or robust and quite incorrect (much of the naive physics knowledge is of this type). More often, however, in fields such as biology or even history, the knowledge is vague and ill-formed. In still other cases, such as mathematics, the right knowledge is only partly defined so that the right sets of actions (for example, adding) or fundamental conceptions (whole numbers) are used in the wrong situation (adding fractions).

Prior knowledge about a topic has a major impact on what a student learns from a particular instructional exchange. The question for teachers is what to do about it. They can ignore prior information and build a new set of knowledge, parts of which might be expected to overlap with previous knowledge. The difficulty here is that deep misconceptions may seriously hamper future knowledge growth or application of knowledge. Alternatively, teachers can help students build up from existing knowledge, making explicit their own prior knowledge and then incrementing it. Teachers can help students actively confront their own beliefs and revise them, for example, through class discussion. The disadvantage is that there may be socially negative consequences if the confrontation becomes personal. Magdelene Lampert, among others, shows how to prevent this by capitalizing on the energy and creativity among students, letting them, under stringent social rules, pose and refute ideas in a social arena.

Of all of the "new" ideas, the social nature of learning and teaching is probably the most radical.

Edward A. Wynne

Social and Cultural Roles

The discussion about multiple types of knowledge and the role of prior knowledge in learning leads to consideration of the social nature of learning and teaching. Of all of the "new" ideas, this is probably the most radical. It is a dramatic departure from the approaches that grew out of behaviorism and its emphasis on individualization. Recognizing that knowledge is, to a large extent, both individual and community property suggests that attention be given to both a student's own individual growth of information and the growth of shared knowledge. Public and shared definitions of problems, tasks, and solutions have a number of potential advantages.

Many modern researchers share several core assumptions about learning. First, learning is an active process of knowledge construction and sense-making by the student. Second, knowledge is a cultural artifact of human beings: we produce it, share it, and transform it as individuals and as groups. Third, knowledge is distributed among members of a group, and this distributed knowledge is greater than the knowledge possessed by any single member.

One pedagogical problem is how to use knowledge of facts, principles, actions, and representations that is available within the group — or the classroom — to help individuals and groups gain more knowledge.

Proposed solutions include an emphasis on "authentic" tasks. A task can be authentic because it is part of the world outside of school (for example, a grocery store) or because it is a part of the culture of a particular discipline (such as mathematics or chemistry).

Another view on this, though, is to consider a school as having its own social system with its own artifacts and sense of authenticity. In such a culture of ideas and meanings, thought and reasoning are valued for themselves, not only for what they can do in the "real world." Both conceptions, however, suggest powerful changes in the dynamics of classrooms, changes that lead to learning.

By building upon the social nature of learning, we may be able to solve some of the problems of mechanistic and fragile knowledge that seem to have plagued the American educational system.

In classrooms that recognize their inherently social nature, talk, public reasoning, shared problem solving, and shared projects all play a vital role. For example, in a class trying to understand the Declaration of Independence, the words must be read and re-read, aloud, in order to discover the meaning of the political concepts and to decipher the meaning of words as they were used in Colonial times. Phrases and sentences have to be discussed and debated. Reflections on the background of the authors, their social settings, and their assumptions have to be made. Prior actions and meetings of the men who wrote the document could be discussed. Far more depth could be gained from this shared experience than would be possible if each student were required to read all of the background material.

In this kind of classroom, the role of the teacher is that of a highly knowledgeable member of the community — a guide, not simply an interactive textbook. Teachers and students together track the progress of the group's understanding (metaknowledge); accept or refute proposed interpretations of others (background factual knowledge); propose interpretations of their own (reasoning); and both increase the demand of the task and reduce its difficulty by sharing it.

Using the classroom as a social arena for the public examination of ideas does three important things. First, students gradually gain competence in using terminology and in generating actions within a discipline — in this case, interpreting an historical document (thus rehearsing the facts, actions, and competencies of a discipline). Second, in the course of dialogue, students naturally build on or refute old ideas as they are merged with new knowledge (thus activating and using prior knowledge). Third, and most important, actions of discussion, proof, and explanation are merged with the network of concepts and principles that are a part of a particular subject matter. Thus inert, isolated information is transformed into more generative, usable knowledge.

There Really Are Some Changes

Notable progress has occurred in the research on learning. I have focused here on three ideas that have consequences for teaching. First, the recognition that there are multiple kinds of knowledge suggests that neither teaching simple hierarchies of actions nor simply having students work with hands-on materials in an unfocused way will result in the deep, conceptual kind of learning that we hope students gain.

Second, the recognition that students bring prior knowledge to new learning suggests that teachers need to make this knowledge explicit, then build upon it or, if necessary, challenge it.

The third idea is the social nature of knowledge and learning. When students talk to each other, they rehearse the terminology, notational systems, and manner of reasoning in a particular domain, thus reducing the individual burden of complete mastery of material while keeping the vision of the entire task in view. By building upon the social nature of learning, we may be able to solve some of the problems of mechanistic and fragile knowledge that seem to have plagued the American educational system.

These three constructs have important implications for transforming the way teaching and learning occur in our classrooms.

Suggested Readings

Types of Knowledge

Chi, M. T. H., and S. Ceci. (1987). "Content Knowledge: Its Role, Representation and Restructuring in Memory Development. In *Advances in Child Development and Behavior*, edited by H. W. Reese, Vol. 20, pp. 91-142. New

York: Academic Press.
Hiebert, J., ed. (1986). *Conceptual and Procedural Knowledge: The Case of Mathematics.* Hillsdale, N.J.: Erlbaum.
Lampert, M. (1986). "Knowing, Doing, and Teaching Multiplication. *Cognition and Instruction* 3, 4: 303-342.
Leinhardt, G. (1988). "Getting to Know: Tracing Students' Mathematical Knowledge from Intuition to Competence." *Educational Psychologist* 23, 2: 119-144.
Polya, G. (1954). *Induction and Analogy in Mathematics.* Princeton, N.J.: Princeton University Press.
Schoenfeld, A. H. (1989). "Teaching Mathematical Thinking and Problem Solving." In *Toward the Thinking Curriculum: Current Cognitive Research*, edited by L. B. Resnick and L. E. Klopfer, pp. 83-103. Alexandria, Va.: Association for Supervision and Curriculum Development.
Scribner, S. (1984). "Studying Working Intelligence." In *Everyday Cognition: Its Development in Social Context*, edited by B. Rogoff and J. Lave, pp. 9-40. Cambridge, Mass.: Harvard University Press.

Prior Knowledge

Bereiter, C., and M. Scardamalia. (1985). "Cognitive Coping Strategies and the Problem of "Inert" Knowledge." In *Thinking and Learning Skills: Current Research and Open Questions*, edited by S. F. Chipman, J. W. Segal, and R. Glaser, Vol. 2, pp. 65-80. Hillsdale, N.J.: Erlbaum.
Bransford, J. D., and M. K. Johnson. (1972). "Contextual Prerequisites for Understanding. Some Investigations of Comprehension and Recall." *Journal of Verbal Learning and Verbal Behavior* 11: 717-726.
Confrey, J. (1990). "A Review of the Research on Student Conceptions in Mathematics, Science, and Programming." In *Review of Research in Education*, edited by C. Cazden, Vol. 16, pp. 3-56. Washington, D.C.: American Educational Research Association.
McKeown, M., I. Beck, G. M. Sinatra, and J. A. Loxterman. (In press). "The Contribution of Prior Knowledge and Coherent Text to Comprehension." *Reading Research Quarterly.*
McCloskey, M. (1983). "Intuitive Physics." *Scientific American* 122-129. [March issue]
Minstrell, J. (1982). "Explaining the 'At Rest' Condition of an Object." *The Physics Teacher* 10-14. [January issue]
Pearson, D. P., J. Hanson, and C. Gordon. (1979). "The Effect of Background Knowledge on Young Children's Comprehension of Explicit and Implicit Information. *Journal of Reading Behavior* 11, 3: 201-209.
Roth, K. J. (1989-90). "Science Education: It's Not Enough to 'Do' or 'Relate.'" *American Educator* 13, 4: 16-22, 46-48.
Schank R., and R. Abelson. (1977). *Scripts, Plans, Goals, and Understanding: An Inquiry into Human Knowledge Structures.* Potomac, Md.: Lawrence Erlbaum Associates.
Smith, D. C., and D. C. Neale. (1991). "The Construction of Subject-Matter Knowledge in Primary Science Teaching." In *Advances in Research on Teaching*, edited by J. Brophy, Vol. 2, pp. 187-243. Greenwich, Conn.: JAI Press.
Spilich, G., G. Vesonder, H. Chiesi, and J. Voss. (1979). "Text Processing of Domain-Related Information for Individuals with High and Low Domain Knowledge." *Journal of Verbal Learning and Verbal Behavior* 18: 275-290.

Social Nature of Learning

Brown, J., A. Collins, and P. Duguid. (1989). "Situated Cognition and the Culture of Learning." *Educational Researcher* 18, 1: 32-42.
Carraher, T. N., D. W. Carraher, and A. D. Schliemann. (1983). "Mathematics in the Streets and in Schools." *British Journal of Developmental Psychology* 3, 1: 21-29.
Cognition and Technology Group at Vanderbilt. (1990). "Anchored Instruction and Its Relationship to Situated Cognition." *Educational Researcher* 19, 6: 2-10.
Greeno, J. G. (1988). *Situations, Mental Models, and Generative Knowledge.* (IRL Rep. No. IRL88-0005). Palo Alto, Calif.: Institute for Research on Learning.
Leinhardt, G. (1988). "Situated Knowledge and Expertise in Teaching." In *Teachers' Professional Learning*, edited by J. Calderhead, 146-168. London: Falmer Press.
Newman, D., P. Griffin, and M. Cole. (1989). *The Construction Zone: Working for Cognitive Change in School.* Cambridge, England: Cambridge University Press.
Palincsar, A., and A. Brown. (1984). "Reciprocal Teaching of Comprehension-Fostering and Comprehension-Monitoring Activities." *Cognition and Instruction* 2: 117-175.
Resnick, L. B. (1987). "Learning in School and Out." *Educational Researcher* 16: 13-20.
Resnick, L. B., and L. E. Klopfer, eds. (1989). *Toward the Thinking Curriculum: Current Cognitive Research.* See especially: "A Perspective on Cognitive Research and Its Implications for Instruction," pp. 173-205, by J. D. Bransford and N. J. Vye; and "Research on Writing: Building a Cognitive and Social Understanding of Composing," pp. 104-128, by G. A. Hull. Alexandria, Va.: Association for Supervision and Curriculum Development.
Rogoff, B., and J. Lave, eds. (1984). *Everyday Cognition: Its Development in Social Context.* Cambridge, Mass.: Harvard University Press.
Säljö, R., ed. (1991). *Learning and Instruction* 1, 3. [special issue on culture and learning].

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