

Transforming America's Schools

by Jonathan Potts



If your child gets sick, you wouldn't give her medicine that hadn't been tested to make sure it works. You wouldn't take her to a pediatrician who didn't rely on sound medical research. Yet few of us even blink at sending our children to schools where even the most gifted teachers are unfamiliar with the best research into how children think and learn.

Just ask Elida Laski. A former kindergarten teacher, she was a literacy coach in the Boston public schools when she discovered how little her fellow teachers knew about educational research.

"Education suffers to the extent that teachers are guided often by their own intuition and their own philosophies, so instruction can vary greatly from classroom to classroom and from school to school. Few teachers are guided by established learning theories," Laski said.

Now, Laski is in a position to do something about it. She's enrolled in the Program in Interdisciplinary Educational Research (PIER), a Carnegie Mellon initiative to train doctoral students from several disciplines—including psychology, computer science, philosophy and statistics—to conduct applied educational research. PIER is funded through a 5-year, \$5 million U.S. Department of Education grant.

PIER is but a single example of Carnegie Mellon's multi-faceted education research initiatives. Decades of research examining human thought and learning have produced revolutionary advances in education technology and teaching methods. Although the university has no education school, its interdisciplinary culture has propelled researchers in departments ranging from Psychology to Statistics to Computer Science to produce innovations that are revolutionizing K-12 and college classrooms. Among the most exciting examples is Cognitive Tutor, a comprehensive secondary mathematics curriculum and computer-based tutoring program that is in use in 2,000 schools nationwide, thanks to the spin-off company Carnegie Learning, Inc.

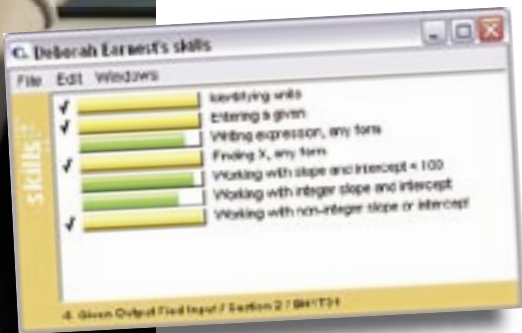
All the university's education programs share a common goal: to raise student achievement through rigorously tested technology and curricula and to help teachers and school administrators make data-driven decisions to improve learning.

The first step is to produce the research, which is where PIER comes in. In addition to fulfilling the requirements of their own departments, PIER students are required to take a three-course sequence to train them to perform education research. They must complete a field project in an educational setting—working either in the classroom or with school administrators—and their dissertations must address an education question. In exchange, the students receive a generous stipend and up to \$12,000 toward tuition. Now in its second year, PIER has 11 students.

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David Klahr



▲ For many students, success in algebra I can be the turning point, leading them to more advanced mathematics and science courses. Because of its individualized instruction, Cognitive Tutor algebra I gives every student a better chance to achieve success.

Another major component of the university's strategy to bridge the gap between university research and K-12 and college classrooms is the Pittsburgh Science of Learning Center (PSLC), jointly launched by Carnegie Mellon and the University of Pittsburgh with a \$25 million grant from the National Science Foundation. At the heart of the center is a research facility called LearnLab where scientists from around the world can run innovative studies in real classrooms and use volumes of data from student use of educational technology to

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Kenneth Koedinger

advance our understanding of how people learn.

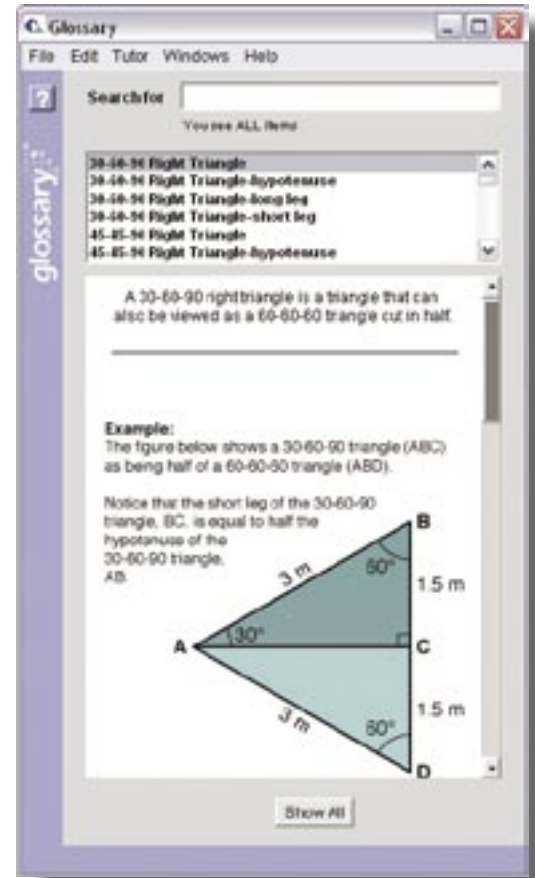
A key focus is on understanding "robust learning" that leads to knowledge students retain, apply to new situations and put to use to learn more quickly in the future.

This research comes at a pivotal time for K-12 education. Never before have

public schools been under more pressure to boost student achievement. The federal No Child Left Behind Act requires schools to demonstrate "adequate yearly progress" on various standardized tests. But integrating quality educational research into public school curricula is not easy. Too often, classroom research lacks scientific rigor while sophisticated, highly refined laboratory experiments have little real-world relevance.

"This is an idea whose time has come," said Kenneth Koedinger, an associate professor of human-computer interaction and psychology at Carnegie Mellon and co-director of the PSLC. "We are not getting the high-quality, useful research we need to meet federal goals to improve education. LearnLab will provide a much-needed infrastructure to produce such research."

LearnLab scientists initially are using two high school and five college-level courses as a basis for their research. The PSLC will invite schools in the Pittsburgh area and across the country to participate as "research schools" and serve much as research hospitals

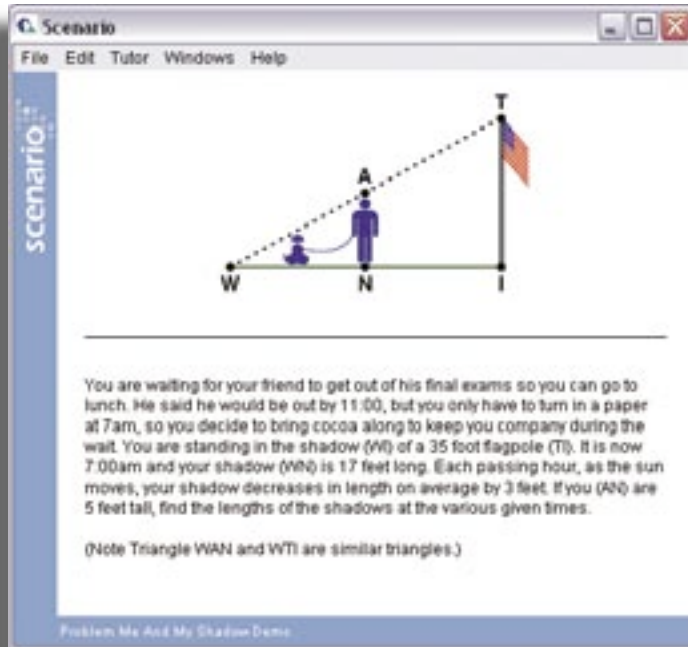
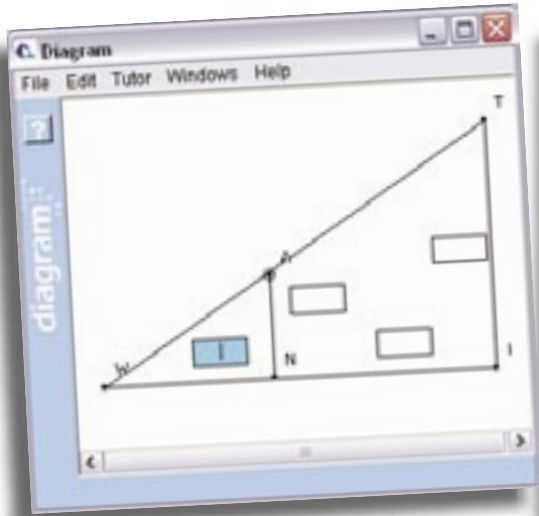


▲ The Cognitive Tutor Geometry (above and opposite page) uses collaborative classroom exercises, software sessions and innovative problem-solving to help students develop the skills and knowledge needed to progress from concrete to abstract thinking. Its connections to algebra advance student learning by building on prior knowledge.

do for medical research.

Not that Carnegie Mellon is starting from scratch. Koedinger, for example, was one of the developers of software systems, such as Cognitive Tutor, that provide students with individualized instruction in a specific subject. These intelligent tutoring systems grew out of the pioneering work of John R. Anderson, the Richard King Mellon University Professor of Psychology and Computer Science, who began developing the system in the 1980s.

In the early 1990s, the Pittsburgh Public Schools piloted Cognitive Tutor Algebra, and last year the district adopted the program as its algebra 1 curriculum. The U.S. Department of Education has designated Cognitive Tutor an exemplary program and named Cognitive Tutor is one of only five off-the-shelf middle school mathematics programs whose



effectiveness had been demonstrated through research.

“Way back in 1992, we had huge numbers of kids who were bombing out in algebra and they didn’t get any further than that. Algebra was the academic gatekeeper,” said Jacklyn Snyder, a veteran teacher and the mathematics curriculum specialist with the Pittsburgh Public Schools.

The technology that drives intelligent tutoring systems is grounded in research into artificial intelligence and cognitive psychology, which seeks to understand the mechanisms that underlie human thought, including language processing, mathematical reasoning, learning and memory. As students perform problems using these tutoring systems, the program analyzes their strengths and weaknesses and on that basis provides individualized instruction. Intelligent tutoring systems do not replace teachers. Rather, they allow teachers to devote more one-on-one time to each student and to work with students of varying abilities simultaneously.

“That differentiated instruction enables the kids who are able to go faster to do more, and it still satisfies the needs of kids who need remediation,” Snyder said.

Snyder said Cognitive Tutor has no parallel in other educational software. It helps students to understand the practical applications of algebra better than conventional teaching methods, and it more clearly illustrates the connections between concepts, she said.

A World of Learning

By Jonathan Potts

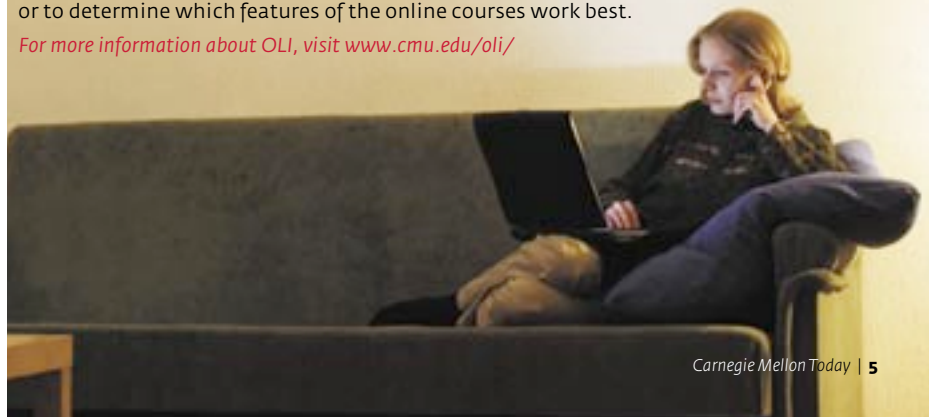
Imagine being able to take a Carnegie Mellon course without leaving the comfort of your home. Now imagine being able to take 10. This is no pipe dream. In 2002, the university launched the Open Learning Initiative (OLI) to develop online versions of high-demand courses.

And this isn’t just any online learning opportunity. Behind every course offering is Carnegie Mellon’s collective expertise in cognitive psychology and human-computer interaction. Take an OLI course, and you get Carnegie Mellon quality instruction, bolstered by the university’s pioneering research into how computers can help people learn.

Carnegie Mellon has received \$3.4 million in grants from The William and Flora Hewlett Foundation to create 10 introductory-level courses, ranging from statistics to biology to French. Already OLI offers courses in several disciplines, including logic, economics and causal reasoning, along with a physics course based on a computer tutor developed at the University of Pittsburgh. The courses are designed to be taken wholly online or to complement conventional classroom instruction. The courses are free to use by individuals and available for a fee to institutions that offer them for credit.

While students are learning, so are Carnegie Mellon professors. An interdisciplinary group of researchers is testing several courses to determine whether students learn key concepts better using the online version or from a traditional lecture, or to determine which features of the online courses work best.

For more information about OLI, visit www.cmu.edu/oli/



“The students like it because they feel they are working at their own pace and they get feedback on what they are doing. If they understand something, they get to move onto new problems,” said Diane Briars, program officer for mathematics and science in the Pittsburgh Public Schools.

In 1998 Carnegie Mellon formed Carnegie Learning to market, distribute and develop intelligent tutoring curricula. In addition to algebra I, the company offers Cognitive Tutor curricula in algebra II, geometry, integrated mathematics and quantitative literacy. Koedinger has developed a similar system called Assistment that helps teachers prepare their students for state-mandated standardized tests.

The technology has many educational

applications—for example, Elizabeth Jones, head of the Department of Biology and Albert Corbett in Human-Computer Interaction, received a four-year, \$1 million grant in 2002 from the Howard Hughes Medical Institute to use intelligent tutoring systems to teach genetics to Carnegie Mellon students. Another related project is the university’s Open Learning Initiative, an ambitious program to create a series of Web-based versions of Carnegie Mellon courses.

Researchers credit the innovation and interdisciplinary culture at Carnegie Mellon for the university’s success in these varied initiatives. Even without a graduate program in education, Carnegie Mellon is revolutionizing the tools and practices in K-12 classrooms.

No greater challenge confronts educators than the achievement gap between low-income students and their affluent counterparts, and many education reforms are aimed at solving this problem.

Supported by a grant from the U.S. Department of Education, Carnegie Mellon psychologists Junlei Li and David Klahr set out to boost science achievement in four low-income, predominantly African-American middle schools in the Catholic Diocese of Pittsburgh.

The goal of the project, now in the third and final year, is to raise student performance on standardized tests by training teachers to craft lessons based on cognitive models of scientific reasoning.

The lessons emphasize key scientific concepts, such as experimental design, over the memorization of facts.

During the first year, researchers tested students before and after they received the lessons. Fewer than 20 percent of students were proficient in experimental design skills before the lessons; afterward, 80 to 90 percent had mastered the concept. Students made as much progress in two weeks as students at an affluent school made in four years with the regular science curriculum, and on selected standardized test questions, the low-income students exceeded national and international averages.

But Li and Klahr have discovered that to prepare students for standardized tests, teachers must cover an extraordinarily large number of topics during a given year, which means they must sacrifice the depth of knowledge that the Carnegie Mellon researchers emphasized. Inevitably, teachers run out of time, and disadvantaged students, who may need extra interventions to overcome the effects of poverty, lose out. It is an issue that policymakers who craft academic standards should address, Li said.

“Imagine if a Carnegie Mellon student had to be assessed every year on all the sciences. It would be impossible. But that’s what we’re asking of K-12 students,” Li said.

—Jonathan Potts

