

The Cognitive Tutor™: Successful Application of Cognitive Science

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Carnegie Learning's Cognitive Tutor programs give students the opportunity to receive individualized attention, maximizing the amount of time spent actively learning and mastering fundamental sets of knowledge skills. Cognitive Tutor programs are an innovative application of technology, applied content curriculum and cognitive science. An important component of the program is software that is intelligent. That is, it monitors the status of the student's knowledge on a moment-by-moment basis and tailors course material, based on these continual assessments.

We call this intelligence a cognitive model. Cognitive Tutor curricula use cognitive models to represent the knowledge that an ideal student would possess about a particular subject. In a very real sense our tutors can be said to understand the subject matter because they represent material the same way a student would. It is this understanding that enables Cognitive Tutor products to adapt continually to individual students as they master the material, much as successful human tutors do.

Cognitive Tutor programs are different from other educational solutions because they have a sound theoretical basis that has been proven effective in classrooms.

Solid theoretical base: Our cognitive models are based on John Anderson's ACT theory of human cognition. Anderson, a member of the National Academy of Sciences and professor at Carnegie Mellon University, began work on this theory in the late 1970s and has refined it the years since. Regarded as one of the most robust and mature theories of cognition, Dr. Anderson's work is capable of representing a wide variety of human thinking.

Proven effective: In the early 1980s, Anderson and his colleagues began developing the Cognitive Tutor technology to test the ACT theory. Since then, a wide variety of rigorous research studies have confirmed the effectiveness of the Cognitive Tutor curricula. Typical results show that students who use these tutors perform one grade-letter better than students taught using more conventional methods.

Three of the most effective features of Cognitive Tutor programs are its constant student monitoring, just-in-time help and individualized skills tracking.

Constant monitoring: The tutor uses a process called model tracing. That is, every action performed by the student—entering a value, clicking a button, selecting a menu item—is checked against the cognitive model. Effectively acting in the same way that a human tutor would, if the student action is inappropriate, the tutor will not let the student go astray. Instead, it will guide the student to a correct solution path. The cognitive model recognizes that there are multiple ways to solve any particular problem and the tutor restricts activities only when they would lead the student in the wrong direction.

Just-in-time help: If a student becomes unsure of a solution path, help is readily available by clicking on the help button. The tutor refers to the cognitive model and chooses the most helpful learning path before guiding the student to the next step. The tutor provides progressive levels of help—if the first hint is insufficient, more hints are offered. In addition to the help menus, assistance is offered automatically whenever a student makes a common mistake. In such cases, the tutor responds with a context-sensitive help message that is designed to clarify the lesson and avoid common misperceptions.

Skills tracking: In any given lesson, there may be up to twenty skills for a student to learn. The tutor constantly monitors the student's actions and each action is tied to the larger set of skills that comprise the domain, such as labeling a graph or finding negative slopes. To give meaningful feedback to the student, the tutor estimates the probability that the student has learned each required skill and displays the results in a bar chart called the Skillometer. When students perform a correct action they can measure their progress on the chart, but if they make a mistake the bar chart shows a decrease. The technical term for this process is **knowledge tracing**. When remedial work is required, the tutor picks problems that concentrate attention on the skills in which the student is weak. Students graduate to the next lesson only after sufficiently demonstrating all required skills.

Cognitive Tutor technology represents cognitive science's best effort to capture the effectiveness of a human tutor. In 1999, Carnegie Learning's Cognitive Tutor Algebra I received the distinction of exemplary status from the U.S. Department of Education. The Cognitive Tutor programs are a valuable addition to the classroom as competent teaching assistants—charting a path toward measurable skill sets, monitoring progress and providing the first line of help. Teachers have an opportunity to concentrate on individuals who need their unique attention. The result is a successful learning experience and a well-supported teacher.