Intelligent Tutoring Systems

Scenario

Dr. Crawford teaches algebra at a community college. Because his students come from a variety of backgrounds, some are better prepared than others. On the first day of class, Dr. Crawford explains where the math tutoring lab is located and when it is staffed. Of course tutoring slots fill fast, and the number of students needing assistance far exceeds the available live tutors. This year, Dr. Crawford also mentions the math department's new online intelligent tutoring system, an integral part of the class for everyone. Students work through exercises on the system, which tracks each student's individual approach, flags answers right or wrong, and gives explanations when answers are incorrect, providing relevant instruction only when a student needs it.

As the term progresses, Dr. Crawford sees students benefit from the system's conversational dynamic, which provides encouragement, calls attention to missteps, and allows students to request hints when they are stuck. Belinda, for example, is in the Running Start Program, taking college courses for credit while completing high school. Even though she sometimes isn't sure if she understands a concept, she is uncomfortable asking for clarification in class. The tutoring system lets her test herself, revisit a point of confusion until it is clear, and ask for help if needed.

Monique likes that the math problems concern real-world situations. Though there is more than one way to solve these problems, the intelligent tutor tracks her particular approach, and when she needs help, she gets instruction adapted to the particular solution she is pursuing. She is glad not to be forced to follow a single procedure, which is how some of her previous teachers taught.

Brady has difficulty because English is his second language. He appreciates that the computer tutor is infinitely patient and allows him to take the time he needs to understand the problems and instruction. When he does not understand, he can ask for more specific hints that eventually show him what to do. He uses such examples to generate explanations of the math for himself, and these resources prepare him to solve the next problems the tutor selects for him. Because reading and action are integrated in the tutor, he feels his English is getting better, too.

1 What is it?

An intelligent tutoring system is computer software designed to simulate a human tutor's behavior and guidance. It can assist students studying a variety of subjects by posing questions, parsing responses, and offering customized instruction and feedback. Two of the most important ways in which intelligent systems are distinguished from other types of computer-aided instruction are that they can interpret complex student responses and learn as they operate. The software builds a profile for each student and estimates the student's degree of mastery. This kind of system can alter its tutoring behavior in real time, following differences in individual student strategies or adjusting its knowledge base for more effective interaction with all students. For an intelligent tutor, the goal is not merely to know that a response is incorrect but to recognize where in that response the student has gone wrong. To accomplish this, the system monitors responses through a number of intermediate steps to pinpoint as accurately as possible where and why thinking has gone astray.

2 How does it work?

These tools consist of a base system, which controls the broad structure and logic, and the discrete tutors themselves, which are created when subject-matter experts furnish specific content for each course or discipline. Although tutoring systems differ in how they operate, in general **the software offers exercises to which students provide detailed responses**. An exercise in math or science, for example, would be broken into sequential process-based steps that require students to draw diagrams, type equations, define variables, or otherwise "show their work." The system evaluates each response and flags any spot where a student has gotten off track. Where appropriate, the tutor might offer hints, often at the student's request. During a session, the intelligent tutor creates a profile for each student and records both correct and incorrect replies. It computes a statistical estimate of the student's mastery of the concepts and skills that underlie the exercise. An intelligent tutor will continue to present a student with problems that test a concept until the application's logic determines that the student has mastered the underlying knowledge. Meanwhile it gathers analytical data on all those who interact with the system.

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3 Who's doing it?

A few institutions have developed their own systems, such as the Cognitive Tutor, initially developed at Carnegie Mellon University. This system has been widely implemented in several levels of math and science nationwide, from algebra and geometry for secondary schools to the Genetics Cognitive Tutor that helps Carnegie Mellon students understand such issues as gene interaction and gene regulation. The Andes Physics Tutor, developed at Arizona State University, supports students in introductory physics courses, while the Writing Pal provides tutoring in writing strategies. Writing Pal has been tested extensively with secondary school students and features essay writing practice, game-based practice sessions, and feedback to guide emerging writers. ASSISTments is a free online program developed at Worcester Polytechnic Institute that tutors students in various subjects. The privately developed Knewton system provides custom learning experiences for students in K–12 and higher education as well as intelligent tutors for the GMAT, LSAT, and SAT. The platform provides instant feedback for students while offering important analytic data to instructors and course designers.

4 Why is it significant?

One-on-one, in-person tutoring is effective in guiding students through the learning process. Intelligent tutoring systems attempt to capture the best methods derived from the traditional human model and move beyond it to discover new strategies for teaching and learning. These tutors **offer a mechanism for examining assumptions about how students learn**. For example, a common teaching premise holds that when a student does not understand a process, the instructor should explain it. Researchers using intelligent tutors, however, have discovered that a more effective approach for struggling learners is to have them explain what they understand to the intelligent tutor, which can evaluate each step of the explanation, provide hints, and give the students space and time to work out the process for themselves.

5 What are the downsides?

Intelligent tutoring systems are time-consuming to design and build, requiring considerable manual effort to enter the specific information for each course or area of study. Because of this developmental complexity, free and commercial options have only recently become available for universities to plug and play on their campuses. Also, students can "game" some simple tutoring systems, requesting hints and then ignoring them until the system offers the correct answer. Some educators believe that the provision of a correct answer—even after several hints—can rob students of their motivation to investigate, explore, and discover. Finally, to derive the most value from an intelligent tutor, the system should be integrated into the curriculum and coordinated with complementary pedagogical models such as class discussions, hands-on lab work, and team projects.

6 Where is it going?

The technology for intelligent tutoring systems appears to be poised for wider use. One possibility is for tutors to be programmed and embedded in MOOCs, where the conversational assistance the tutors offer can provide students a sense of instructor interaction that might otherwise be missing. As more students use intelligent tutoring systems, greater amounts of data retrieved from student input can be used to design improvements in the systems themselves. Also, some researchers are working with voice recognition and simulated natural human dialogue to improve the feedback cycle between student and tutor. In this way, intelligent systems might one day be able to respond not just to a student's words but also to tone, facial expression, or body language.

7 What are the implications for teaching and learning?

Intelligent tutoring systems are not designed to replace human mentors, who bring complex social interaction into the learning process. On the other hand, an intelligent tutor can work with a huge number of students—both simultaneously and individually—and can, for example, be available at 11:00 p.m. the night before an exam. Further, a computer-based tutor can reduce the anxiety some students feel about admitting to a human that they don't understand a concept or process. Intelligent tutors have been shown to improve student understanding and assessment scores. An intelligent tutoring system can also provide real-time data to instructors and developers looking to refine teaching methods. Because educational institutions cannot assign a human tutor to each pupil, **intelligent tutoring systems are a useful surrogate to offer any student individual help, calibrated to his or her own learning speed and specific learning requirements**.