Enhancing Learning Using Adaptive Computerized Tutoring in K-12 Settings

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How do we individualize instruction and develop cognitive skills to enhance learning? Computer tutors can provide scalable interventions that tailor instruction to each student. This symposium brings together cognitive scientists, computer engineers, content specialists, and education researchers to address adaptive computerized tutoring—a key topic in both cognitive science and education. The papers represent innovations in cognitive science research drawing from discourse comprehension theory and theories of metacognition. These theories are tested across several cognitive skills (deep-level reasoning, self-regulated learning), within multiple content domains (science, math, computer literacy), and across a range of ages in authentic classroom settings (elementary school to college). In her role as discussant, Stephanie Siler will address the common theme of these projects: finding ways to use intelligent tutoring systems to improve learning through thinking and reasoning, consistent with these theories. Carol O'Donnell, Program Officer for the Cognition and Student Learning Research Program at the Institute of Education Sciences, and Robin Harwood will moderate this panel and facilitate discussion throughout the symposium.

An Implementation of Vicarious Learning with Deep-Level Reasoning Questions in Middle School and High School Classrooms

The overarching goal of our research (Gholson, Graesser, & Craig) is to expose deep-level reasoning questions in the areas of computer literacy and Newtonian physics to middle school and high school students and to show how they support knowledge construction during vicarious learning. We compared an interactive intelligent tutoring system called AutoTutor to a learning environment called iDRIVE (Instruction with Deep-level Reasoning questions in Vicarious Environments). The iDRIVE system provided vicarious learning in which students listened to and observed the AutoTutor agent presenting the same course content, but students did not adaptively interact with the materials. Results from the first study indicate that 342 8th-11th grade students showed greater learning gains in Newtonian physics and computer literacy when assigned to the iDRIVE condition (in which content sentences were each preceded by a deep-level reasoning question) than those learners who were presented with the same content offered in a monologue condition (no deep-level reasoning questions). This finding in favor of iDRIVE has implications for return on investment because it is more costly to develop an interactive AutoTutor than to script an exchange with iDRIVE.

Our first classroom comparison involved six classrooms of 8th graders (n = 160) randomly assigned to an iDRIVE condition (computerized version), monologue condition (computerized version), or standard pedagogy in which students received standard instruction given by their teachers. The iDRIVE software produced learning pretest to posttest learning gains equal to or greater than those produced by master classroom teachers on a variety of measures. A second randomized intervention paired various conditions with classroom instruction. iDRIVE software taught the conceptual component of two units of high school physics, used three vicarious conditions: standard monologue condition, standard iDRIVE condition, and an iDRIVE condition with an additional explanation. Findings indicate that students in the two iDRIVE conditions performed better than students in the monologue condition. Current findings from these two studies appear to confirm results from our laboratory experiments.
A Learning by Teaching Approach to Help Students Develop Self-Regulatory Learning Skills in Middle School Science Classrooms

To help students develop metacognitive self-regulatory learning (SRL) skills in middle school classrooms, we (Biswas, Schwartz, & Catley) implemented a computer-based learning environment called Teachable Agents (TAs), where students learn by teaching a computer agent called Betty. Students monitor, assess, and reflect on their own learning by asking Betty questions and observing her performance on quizzes provided with the system. The belief that they help their agent learn motivates the students and guides them toward metacognitive activities that aid their learning. Additional metacognitive support is provided by Betty's persona, who demonstrates the use of self-regulation strategies in her interactions with her student teacher. In Tennessee, we conducted several studies in 5th grade science classrooms that measure student learning by the quality of the students' concept maps produced while teaching their agent. We found that learning-by-teaching with metacognitive support helped students learn about river ecosystems and better prepared them for future learning on related topics. The cover story of teaching an agent led to more complete and interconnected concept maps. Learning outcomes were strongest for students who also received metacognitive feedback from Betty. These differences persisted during a transfer phase in which students learned about a new domain and taught their agent in the absence of most feedback and prompts. We have also studied students’ activity patterns as they teach their agent. Analysis shows that the quality of students’ concept maps is paralleled by patterns in their behaviors. SRL prompts from the agent seem to help students engage in productive learning interactions. Unlike conventional tutoring that provides feedback on domain content, our tutoring tracks students’ activity patterns and, at appropriate times, provides feedback on SRL strategies.

In experiments in California schools, classes were randomly assigned to a Betty (TA) or Inspiration (commercial concept mapping tool) condition. Over 11 days of the curriculum, we introduced additional technology features designed to enhance SRL and measure learning. Students completed assignments using the online homework environment. Pre-, post-, and midstream-learning measures indicated that the Betty condition showed an increasing advantage over the lesson units, particularly on items that required long chains of inference. The largest benefit occurred when the homework environment was introduced. Betty students were also more prepared to learn from a new unit without any technological support. These studies at Vanderbilt and Stanford suggest the interventions are valuable for improving learning and metacognition as seen in increased abilities to learn in future contexts.

Improving Science Learning through Tutorial Dialogs

In the 2002 National Assessment of Educational Progress (NAEP), only 2% of U.S. students attained advanced levels of mathematics or science achievement by Grade 12. We (Ward & Cole) provide individualized instruction to students through natural spoken dialogs with a virtual tutor that behaves like an expert human tutor. By developing and evaluating the integration of tutorial dialogs by human and virtual tutors in elementary science curricula in large classroom vs. small group settings, we can compare learning gains of students who receive tutoring to students in control conditions. This work is being implemented for children’s science learning in schools that previously performed poorly with FOSS (Full Option Science System), a structured science program shown to work with many but not all students. We will discuss our current development project that uses dialogs based on Questioning the Author (QTA; Beck & McKeown, 2006). QTA uses open-ended questions to help students learn to integrate new concepts with what they know to deepen and expand the knowledge that was presented in class. QTA, shown to improve reading comprehension nationally, uses systematic dialog interaction to foster deep learning. The virtual tutoring system closely resembles tutorial dialogs produced by human tutors trained in the QTA method. Along with elementary teachers, FOSS curriculum developers, QTA experts, and 3rd, 4th and 5th graders in a large city school district in Colorado, we will develop and refine the system using an iterative design process. Students in classrooms will be randomly assigned to receive either (a) standard classroom instruction and support, (b) classroom instruction with support incorporating QTA dialogs in a large group, (c) small-group tutoring with QTA with a trained human tutor, or (d) small group interaction with the computer-based QTA tutoring system.

Discussant

Dr. Stephanie Siler is part of a team with David Klahr and Mari Strand-Cary developing an intelligent tutor to improve elementary and middle school students’ conceptual understanding and procedural skills of designing and interpreting scientific experiments.

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