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Review

Automated, adaptive guidance for K-12 education

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ABSTRACT

This paper distinguishes features of automated adaptive guidance used in K-12 instructional settings and recommends directions for design. We use meta-analysis to synthesize 24 independent comparisons between automated adaptive guidance and guidance provided during typical teacher-led instruction, and 29 comparisons that isolate the effects of specific adaptive guidance design features in computer-based instruction. We find automated adaptive guidance to be significantly more effective than guidance provided in typical instruction, particularly for students with low prior knowledge. Automated adaptive guidance is most effective when students are generating and integrating ideas (e.g. writing essays, making concept diagrams) as opposed to selecting from the given options. Guidance that promoted self-monitoring was more likely to improve learning outcomes than guidance that addressed only content knowledge. Our findings have implications for researchers who investigate K-12 teaching and learning, designers who create and refine instructional materials using automated guidance, and practitioners who deliver or customize instruction featuring automated guidance.

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1. Introduction

Engaging students in reflecting on their ideas, using evidence to sort out their ideas, and constructing arguments and explanations to integrate ideas are known to foster deep understanding (Bransford, Brown, & Cocking, 1999; Furtak, Seidel, Iverson, & Briggs, 2012; Minner, Levy, & Century, 2010). However typical K-12 instruction relies on a combination of lectures and worksheets designed to transmit superficial knowledge rather than support the construction of deep understanding. Furthermore, students are often summatively assessed with multiple-choice tests that encourage the recall of facts without conceptual understanding (Liu, Lee, & Linn, 2011; Shepard, 2008). The classroom emphasis on memorization rather than inquiry and summative rather than formative assessment is due in large part to the challenges associated with guiding diverse students. Posing questions that elicit students' ideas and providing individualized guidance to address the variety of those ideas require more time and expertise than many K-12 teachers have. Pre-college instructors often have 5 or 6 classes with up to 40 students each. They often hold multiple-subject credentials and teach outside of their specialty, especially in the fields of science, technology, engineering and mathematics (STEM) and in schools that serve low-income populations (NSF (National Science Foundation), 2008).

The burgeoning of automated scoring technologies and adaptive guidance for students within online learning environments over the past decade offers promise for responding to this challenge. These tools can help teachers guide students by scoring student work on assessments embedded in online curricula and automating individualized guidance. Such tools may free teachers from the task of evaluating all of their student responses, and allow them to focus more of their efforts on helping students who require further, more complex assistance.

As automated scoring and guidance technologies continue to evolve, so does their potential to encourage students to deepen their explanations – and consequently, their understanding – of complex ideas. Whereas automated guidance was once used primarily for problems with a single right answer, advanced tools can now diagnose student responses on an array of open-ended, generative activities. Researchers are using natural language processing techniques to identify ideas from students' essays, advanced algorithms to analyze conceptual flaws in student-generated representations, and learning sciences principles to diagnose self-monitoring practices in students' logged interactions with the computer. Researchers are investigating designs for effective guidance that can be automatically delivered to students based on these scored responses and practices.

Over the past three decades automated guidance tools have been used and researched primarily in post-secondary contexts, particularly conceptual physics and computer science (e.g. Smith & Sherwood, 1976; VanLehn, 2011). A review of intelligent tutors used in college settings found that student dialogue with a computer tutor was nearly as effective as a dialogue with a human tutor in helping students solve problems in STEM. Both resulted in an average effect size of .7 across comparison studies (VanLehn, 2011).

Automated scoring and guidance tools are now entering the K-12 realm. Researchers are developing and investigating automated guidance tools across K-12 domains such as Language Arts (e.g. Summary Street, Wade-Stein & Kintsch, 2004), Algebra and Geometry (e.g. Cognitive Tutors, Koedinger & Aleven, 2007) and Science (e.g. Betty's Brain, Leelawong & Biswas, 2008). However, reviews of automated guidance in the past 15 years have focused on intelligent tutors in post-secondary contexts (VanLehn, 2011) or Cognitive Tutors exclusively (Koedinger & Aleven, 2007). With the increasing size and diversity of K-12 classrooms, the availability of robust virtual learning environments, greater access in schools to computers, and stable internet connections, there is now both a need and an opportunity to examine automated guidance technologies in pre-college settings.

The K-12 setting poses challenges that are distinct from those in adult education. First, K-12 schooling is mandatory, while adult education is elective. As a result, K-12 students are more diverse regarding their motivation to learn, prior content knowledge, and repertoire of learning strategies. Moreover, K-12 students' success is more reliant on the relationship between student and teacher than the success of typical, higher education students. The K-12 environment offers many instructional supports that might interact with automated scoring. This stands in contrast to the few additional supports in the controlled laboratory environments typically used for experimental research on adult learning. Understanding specifically how K-12 instructional supports can interact with the automated guidance is essential to designing successful approaches to providing automated guidance and will have broad ranging implications for K-12 education.

In this paper, we use meta-analysis to synthesize current research on automated, adaptive guidance implemented across domains in K-12 classrooms. Two research questions guide our analysis: