Effects of web based tutoring software on students' math achievement

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Background: Intelligent tutoring systems. Computer-based intelligent tutoring systems (ITS) provide one promising option for helping students prepare for high stakes assessments. Research on intelligent tutoring systems has clearly shown that users of tutoring software can make rapid progress and dramatically improve their performance in specific content areas. Although much ITS research focuses on military, industry, and other non-academic training situations, evaluation studies of several ITS for school mathematics also show benefits to student users in school settings. Specifically, studies of the Carnegie Tutor (CMU) for algebra and the AnimalWatch tutor (UMass-Amherst) for arithmetic indicate that student users successfully master specific skills and that their attitudes towards math become more positive as a result of working with the software (< www.carnegielearning.com >; Arroyo, Beck, Schultz & Woolf, 1999; Beal & Arroyo, 2002). However, existing ITS are limited in several ways. First, as stand-alone applications that must be installed on individual computers, they are difficult to disseminate, update and extend. Second, although they provide effective instruction, few ITS have really taken advantage of the instructional possibilities of dynamic multimedia techniques such as animation, techniques that are common in commercial software (Beal, Beck, Westbrook, Atkin, & Cohen, 2002). For example, both the Carnegie Tutor and AnimalWatch systems are basically interactive electronic worksheets. Third, although current ITS model the student's knowledge on an ongoing basis in order to provide effective help when needed, there have been only preliminary attempts to incorporate knowledge of student group characteristics (e.g., profile of cognitive skills, gender) into the tutor and to use this profile information to guide instruction (Shute, 1995).

Objectives. The main goal of the current project is to implement and evaluate a web-based intelligent tutoring system for high-stakes math achievement tests (Beal, Arroyo, Royer, & Woolf, 2003). The system, called Wayang Outpost, currently provides tutoring for SAT-Math problems, but has been designed so that problem content appropriate for other math achievement tests (e.g., the MCAS in Massachusetts) can be added to the existing architecture. Wayang Outpost is designed to provide web-based access to a) tutoring on SAT-Math problems, using information about the student's cognitive profile to customize instruction and improve performance on high stakes assessments and b) modules to assess and enhance the student's profile of cognitive strengths and weaknesses.

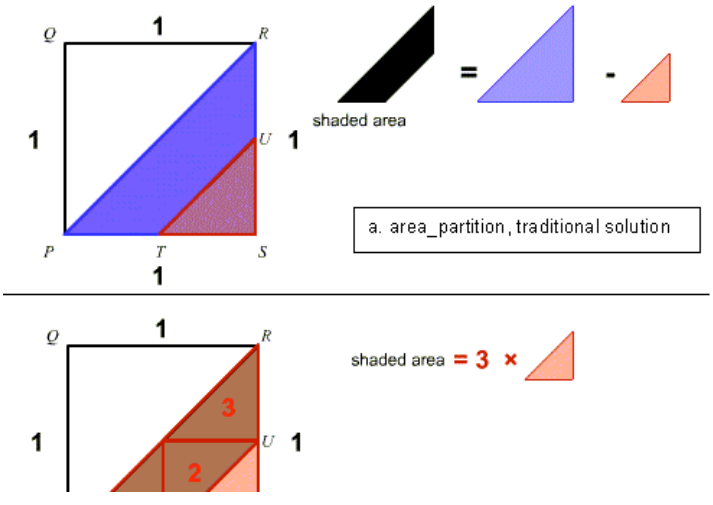
Within the main goal of implementation and evaluation, the project aims to assess three specific objectives. First, it is necessary to determine if the system will function properly in a technological sense when used by students in classroom contexts. For example, can the server handle multiple users? Do all files load appropriately? Does the audio coincide with the Flash files? In short, the project aims to verify the technological integrity of the system. Once it is

clear the system is functioning well in real classroom conditions, a second goal is to ensure that students are learning as the result of the instruction provided by the tutor. Transfer of knowledge from the Wayang tutor to the SAT post-test is one indicator that will help to assess this objective. A third aim is to gather students' perceptions of the system. Student and teacher feedback is integral in updating the system.

Tutoring via web-based multimedia. Wayang Outpost provides instruction via a web site, ensuring easy access to students either at home or from any school connected to the Internet. Use of the web delivery format allows easy expansion and frequent updating of the system, without requiring users (students or teachers) to download or reinstall the program. The student begins a session by logging into the site and receiving a math problem. The setting is a Flash animated classroom based in a research station in Kalimantan (formerly, Borneo), populated by researchers, visitors, and students interested in environmental issues, which provides rich real-world content for mathematical problems.

Each math problem (currently, a battery of SAT-Math problems provided by the College Board) is presented in a Flash movie, including an animated character based on the traditional Indonesian art form of shadow puppetry (Wayang; hence the name of the system). If the student answers incorrectly, or requests help, the teacher character provides step by step instruction and guidance in the form of Flash animations with audio. For example, on a geometry problem, the student might see an angle with a known value rotate and move over to the corresponding angle with an unknown value on a parallel line, thus emphasizing the principle of correspondence, while the teacher describes the relation. The explanations and hints provided in Wayang Outpost therefore resemble what a human teacher might provide when explaining a solution to a student, e.g., by drawing, pointing, and gesturing while talking, in contrast to previous mathematics ITS which relied heavily on screen-based text and static examples.

Each problem includes two types of hints: one based on an algebraic, step by step approach, the second based on mental rotation and visual estimation (a strategy that past research suggests is more often used by male students). An example is shown here. The choice of hint type can be customized for individual students on the basis of their cognitive profile, to help them develop strategies and approaches that may be more effective for particular problems. For example, women who score low on the spatial ability assessment might receive a high proportion of hints that emphasize mental rotation and estimation, approaches that women often avoid even though they are generally



more effective in a timed testing situation.

Evaluation. In Spring 2003, students in math classes (Algebra-2 and AP Calculus) in two high schools in Western Massachusetts participated in an evaluation study (N = 75). Students first completed a paper-and-pencil pretest which was, basically, a mock SAT exam, including math problems chosen to draw upon the skills emphasized in the tutoring module, as well as problems that the tutor was not designed to target directly. Students also completed an on-line version of the Vandenberg (1978) mental rotation task to assess spatial cognition. Students then worked with the Wayang web site during their regular mathematics classes for between 2 – 5 sessions, depending on the class length (schedules varied daily, with some classes meeting for 25 minutes and others for 90 minutes). Students worked in school computer laboratories with Internet access. At log-in, students were randomly assigned to receive one of two forms of help: Half the students had a high probability of receiving Visual-Estimation-Rotation help when help was requested, whereas the other students had a high probability of receiving Algorithmic help. This design ensured that the overall experience for students in both groups was similar and that all students saw examples of both help types; the only difference was the proportion of the two help types that were shown. Student problem solving data were automatically recorded by the Wayang server into the student model database. These data include latency to enter an answer, accuracy of answer, specific incorrect answers selected, requests for help, etc. In the final session, students again completed a paper and pencil SAT-Math test. Two versions of each pre and post SAT-M test were counterbalanced across participants; no significant differences were observed between the test versions.

The results indicated that students benefited significantly from the tutoring provided by the Wayang website. Overall, a comparison of scores on pre and post tests showed an average improvement of 20% after working with the Wayang tutor, with some students improving considerably more. Students also attempted more problems on the post-test after working with Wayang, suggesting that they had learned new ways to tackle the challenging problems, even if they did not actually get the correct answer. We also had an unplanned control group of 9 students who took the pre and post paper and pencil math tests but did not work with the Wayang website (due to absences or class schedule conflicts). These students showed no improvement in their SAT performance, suggesting that students did not improve simply by taking a mock SAT exam for a second time.

Additional analyses suggested that male and female students differed on average in how they used the software. Specifically, females requested help from the software more often than males, whereas males made more incorrect attempts at answering problems than females. This suggests that female students were more meticulous in their approach, asking for help instead of making numerous incorrect attempts. Females also spent more total time in the system, though males and females did not significantly differ on the total number of problems viewed. Again it seems as though the females were taking their time in the system, whereas the males were rapidly moving through the tutor neglecting the

help and opting to guess, thus making more attempts. Males outperformed females on our on-line version of the Vandenberg mental rotation task. This finding is consistent with previous research.

At the end of our evaluation study, students were asked to complete a survey about their perception of the software. It is clear that the general reaction was highly positive: e.g., "The help was excellent. I wish I could have had another day so I could have gotten more out of it"; "I thought the explanations were put together very well because I could understand them. I really liked the animations. The way that I learn is by seeing things worked out, so it was very good. I thought that it was put together very well and would help students study for the SATs"; "I'm going to go home and definitely use it to study!"; "I really liked the math adventure. It was interesting because of the animations and audio and involved real life problem situations"; "I liked it because it was like a computer game. It made math more fun and easy to follow."

The Wayang Outpost research project is a preliminary first step to web based educational technology that can be used by students as a supplement to their mathematics classroom experience, either in school or at home. It is an important milestone in creating educational materials that will be available to all students. Preliminary analyses attest to its benefits for students, and future studies will aim to explore its potential in other areas and with a wider variety of problems. A demonstration of the system will be provided at the poster via laptop.

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