Woolf, B.P., Arroyo, I., Beal, C. and Walles, R., Customizing a Multimedia Tutor for Students Preparing to Take High Stakes Achievement Tests. ED-MEDIA: World Conference on Educational Multimedia, Hypermedia & Telecommunications, June 2005, Montreal.

Customizing a Multimedia Tutor for Students Preparing to Take High Stakes Achievement Tests

Beverly P. Woolf and Ivon Arroyo
Computer Science Department,
University of Massachusetts, Amherst, U.S.A
{ivon, bev}@cs.umass.edu

Carole Beal[1] and Rena Walles
Department of Psychology,
University of Massachusetts, Amherst, U.S.A
{cbeal, rwalles}@psych.umass.edu
[1]Information Sciences Institute, University of Southern California
cbeal@isi.edu

Abstract. Research suggests that multimedia and individualization of instruction are both effective ways to teach new material. This paper describes the integration of information about individual student cognitive characteristics into an intelligent tutor for high school geometry. The tutor presents a breadth of geometry problems with multimedia animations, embeds problems in narrative and fantasy and selects alternative teaching strategies based on a student's cognitive abilities. We present an evaluation of the tutor that leads to conclusions of effectiveness and provide a guide for future adaptive versions of the tutor.

Multimedia and Customization

Both multimedia and customized teaching have been shown to be effective for learning. Multimedia has been shown to be effective in computer-based teaching and can range from simple graphics and animation to interactive lifelike pedagogical agents in rich, self-explaining 3D worlds (Lester et al., 1997). Advances in media technologies have created unprecedented opportunities for a new generation of knowledge-based learning environments. Some environments exploit artificial intelligence to support next-generation natural language dialogue. Animated pedagogical agents within learning environments can observe students' progress, provide visually contextualized problem-solving advice and play a powerful motivational role.

Students also learn better when teaching material is customized to their learning needs. For example, research in human development points to the central role of one-on-one individualized instruction of the young learner by an older child, a parent, teacher, or other more experienced mentor (Greenfield & Lave, 1982; Lepper et al., 1993). Research suggests that novices construct deep knowledge about a domain through interaction with a more knowledgeable expert (Brown et al., 1994; Ericsson et al., 1993; Graesser et al., 1995).

Multimedia techniques are common in commercial software (Beal et al., 2002) and have produced higher learning when present in educational software (Mayer, 2001). Yet, tutors that use intelligent agents to individualize teaching have not really taken advantage of the instructional possibilities of dynamic multimedia techniques. This paper describes the integration of both multimedia and customized responses based on knowledge about a student's cognitive characteristics and gender.

Although current intelligent tutors model a student's knowledge to provide effective help, only preliminary attempts

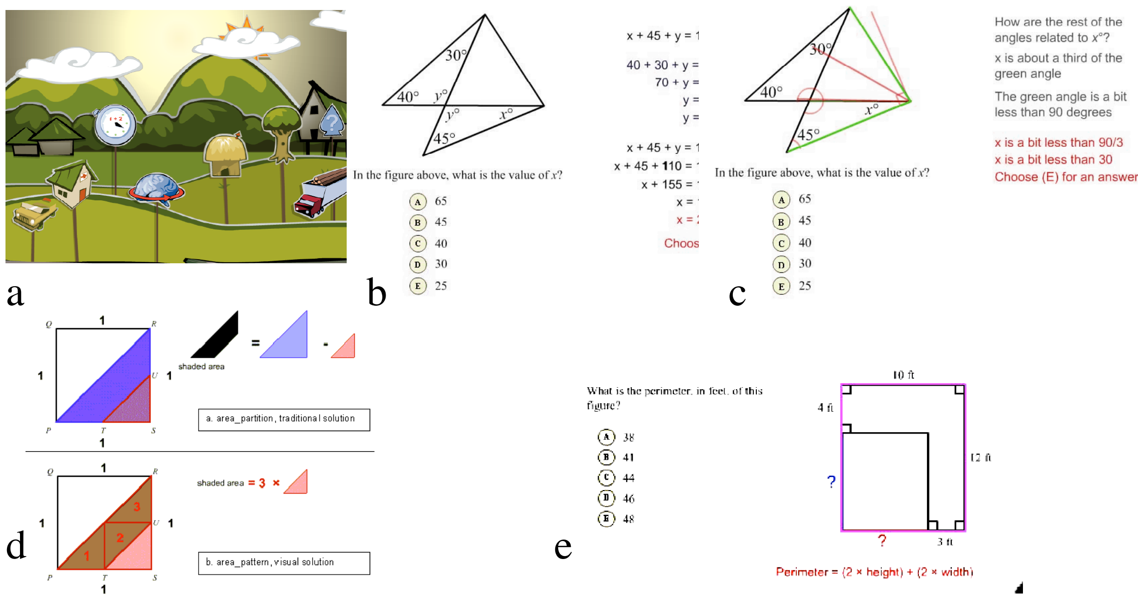

Figure 1. Wayang Outpost provides customized hints in geometry. An orangutan research laboratory in Borneo serves as the environment for *Wayang Outpost*, a multimedia tutor for high stakes testing (e.g., SAT geometry). The Wayang Outpost Village provides top-level navigation for modules, such as pre-tests, SAT problems and adventures (a). Two forms of help are available for each problem, including fairly traditional analytic hints, such as setting up equations along with visual hints and animated lines to support rapid estimation and novel thinking about geometry.

have been built to incorporate knowledge of student group characteristics (e.g., profile of cognitive skills, gender) into tutors and to use this information to guide instruction (Shute, 1995; Arroyo et al., 2000). The benefits of customized tutoring are especially clear for those students with relatively poor skills and for under-represented students in some fields, e.g., minorities and women in science courses.

Research has clearly shown that intelligent tutors support rapid learning and dramatically improve student performance. Tutors such as the Algebra Tutor (Koedinger et al., 1997) for algebra and AnimalWatch tutor (Arroyo et al., 2000; Beck et al., 2000) for arithmetic, indicate that students successfully master specific skills and that their attitudes towards math become more positive as a result of working with the software (Arroyo, 2003; Beal & Arroyo, 2002).

Mathematics education is one discipline that has profited from the use of multimedia. Johari (2003) examined the effects of two inductive multimedia programs, one including use of a coordinate graph and its language, on university students' ability to conceptualize variables and create equations from word problems. The programs were designed to address the problem of syntactic and semantic translation misconceptions in mathematics problems. Results suggest that inductive multimedia facilitates the incorporation of many instructional strategies including inquiry learning from data, tutorials, schema, and core representational systems. The results are consistent with propositions recognizing the conceptual richness of visuals, specifically the coordinate graph, in mathematics education. Researchers using multimedia in mathematics education are cautioned to focus the multimedia on teaching inductive problem-solving strategies or scientific heuristics (for example, by working backwards, working inductively, or applying algebraic thinking to data) (Martinello & Cook, 2000) and to include the language of mathematics and math visuals (graphs) (Kaput, 1992).

The SAT high stakes achievement tests have become increasingly important in the past years in the U.S.A. and a student's performance on such tests can have a significant impact on his or her access to future educational opportunities such as admission to universities and scholarships. New approaches are required to help all students perform to the best of their ability on these tests. Wayang Outpost, an intelligent tutor with real-time multimedia help reasons about a student’s cognitive characteristics while preparing them for the mathematics section of the

Standard Achievement Test (SAT). The next three sections describe Wayang Outpost and how it uses information about a student's cognitive skills to customize instruction and improve performance.

Tutor description

Wayang Outpost helps students learn to solve geometry problems typical of those on high stakes achievement tests, which may require the novel application of skills to tackle unfamiliar problems, as well as the need to work quickly due to the time constraints imposed by the testing situation. As a Web-based activity, Wayang Outpost ensures easy access for students either at home or from any school connected to the Internet[1]. The setting is an animated classroom based in a fictitious and simulated research compound in Borneo, which provides rich real-world context for mathematical problems involving endangered species material, Figure 1(a). When the student first enters the site, she is presented with a multiplicity of activities. An orangutan research laboratory in Borneo serves as the major environment and the Village provides top-level navigation for modules, such as pre-tests, SAT problems and adventures.

A battery of SAT-Math problems are each presented in a Flash movie and include animated characters 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, multimedia explanations provide step-by-step instruction and guidance in the form of Flash animations with audio. Two forms of help are available for each problem, Figure 1 (b-e). 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, Figure 1 (b and c). Explanations and hints therefore resemble what a human teacher might provide when explaining a solution to a student, e.g., by drawing, pointing, highlighting critical parts of geometry figures, and talking, rather than a heavy reliance on screen-based text.

Students take several pre-tests, complete SAT problems and engage in fantasy adventures, Figure 2, designed to test the geometry principles learned while solving SAT problems. Fantasy problems are situated in real-world contexts that help students transfer geometry problem skills into problems, such as calculating the shortest path to a location, the amount of building supplies needed to repair a building, or the amount of trees being removed by foresters. If the student has difficulty with transfer problems, related but simpler geometry problems are presented to remind the student of the principles.

Cognitive skills assessment

Our earlier research suggests that the assessment of cognitive skills is relevant to selecting teaching strategies or external representations that yield the best learning results. For instance, a study of students' levels of cognitive development in an earlier mathematics tutor, AnimalWatch, suggested that for students at early cognitive development stages, hints that use concrete materials in their explanations yield higher learning than those which explain the solution with numerical procedures (Arroyo et al., 2000). Wayang Outpost also functions as a research test-bed to investigate the interaction of gender and cognitive skills in mathematics problem solving and the selection of the best pedagogical approach.

Previous research has shown that spatial cognition and math fact proficiency are strong predictors of performance on mathematics achievement tests such as the SAT-M exam. Female students tend to score less well than their male peers on spatial ability tasks such as mental rotation, and spatial cognition is correlated with mathematics achievement test scores. Proficiency with basic math facts is also known to correlate with gender, although the relations are complex: among the population of high-achieving students, males tend to retrieve basic math facts from memory more rapidly and accurately than their female peers, whereas the reverse is true for students with poor academic skills. It is suspected that cognitive abilities such as spatial abilities and math fact retrieval are important

[1] Wayang Outpost is available at http://ccbit.cs.umass.edu/wayang.

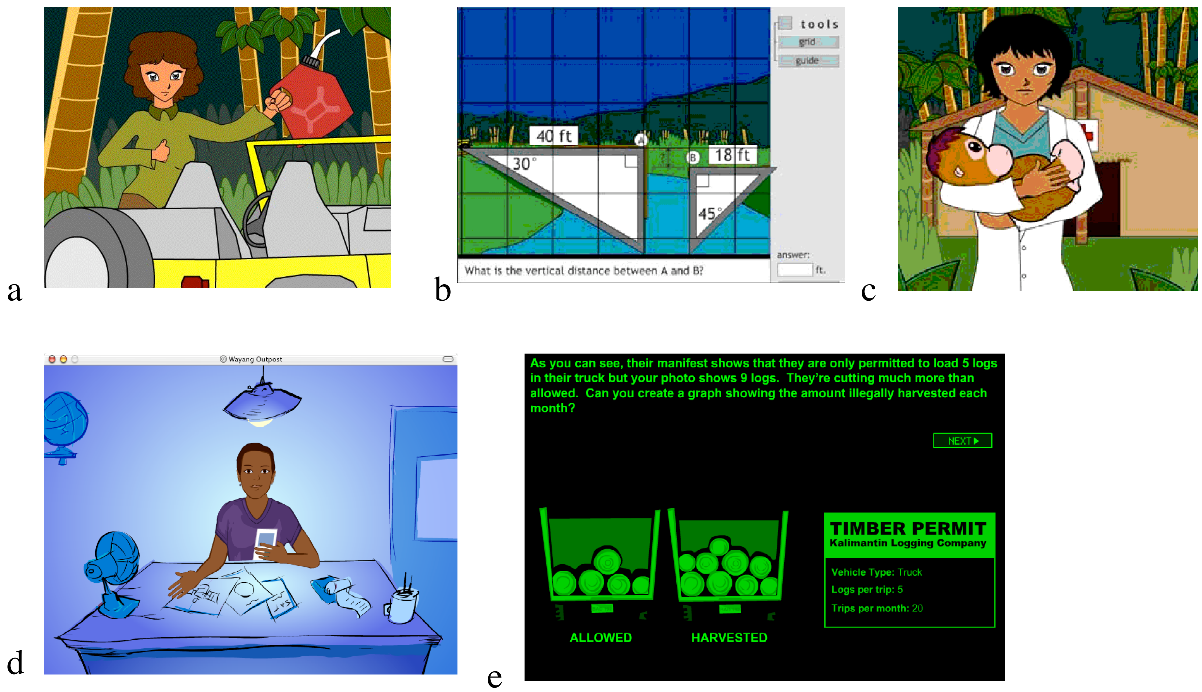

Figure 2. Fantasy component in *Wayang Outpost*. Math adventures test the student's ability to transfer geometry skills from straight problems (Figure 1) to real-world contexts. Anne asks the student to help save three orangutans after a fire broke out in the forest (a). Students are asked to calculate the shortest route and to decide if a jeep can survive a vertical fall across a broken bridge (b). An orangutan nursery is destroyed by a fire and the student is asked to rebuild it (c). In another fantasy, a student is asked to monitor over-logging in the forest, specifically harvesting of the rainforest (d and e). Students calculate discrepancies between the observed and permitted areas of harvest.

determinants of the score in these standardized tests. Math Fact Retrieval is a measure of a student's proficiency with math facts, the probability that a student can rapidly retrieve an answer to a simple math operation from memory. In some studies, math fact retrieval was found to be an important source of gender differences in math problems and SAT-Math problems (Royer et al., 1999). Other studies found that when mental rotation ability was statistically adjusted for, the significant gender difference in SAT-M disappeared (Casey et al., 1995).

Because these cognitive skills are known to relate to SAT-Math performance, students were tested before they used the tutor. On-line assessment tools based on a standard assessment of mental rotation skills (Casey et al., 1997; Vandenberg et al., 1978) measured spatial ability. A separate on-line assessment of the student's proficiency with math facts was made indicating the degree of fluency (accuracy and speed) of arithmetic computation (Royer et al., 1999).

Customized Help in Wayang Outpost

Each geometry problem is linked to two alternative types of hints that follow different strategies for solving the problem: one strategy provides a computational and numeric approach and the second provides spatial transformations and visual estimations, generally encompassing a spatial "trick" that makes the problem much simpler to solve, Figure 1 (b-e). The choice of hint type is 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, students who score high on the spatial ability assessment might receive a high proportion of hints that emphasize mental rotation and estimation, approaches that students of poor spatial ability may not apply even though they are generally more effective in a timed testing situation. This is a major hypothesis we are evaluating, and current findings are described in the evaluation section.

The second form of help, based on spatial transformations and visual estimations, is often rapid and involves fewer computations than the computational strategy. Although estimation methods may be somewhat imprecise in the context of multiple-choice assessments such as the SAT-Math exam, visual-estimation strategies can lead to a plausible correct answer in a relatively short period of time and can reduce the possibility that simple computation errors will result in the wrong answer choice.

For example, a fairly traditional analytic approach provides analytic hints, such as setting up equations, Figure 1 (b). Visual help provided animated figures and lines (c, d, and e). Visual hints (lines added to figures) are also available along with animated lines on the figure that propose that the student mentally translate angles to determine the missing value (c). The traditional way to solve an area partition problem (d), which asks for the area of the shaded region, is by finding the area of the large blue triangle and subtracting the area of the small red triangle (these hints are multimedia-based: triangles move around and sounds play, giving explanations), on the top (d). The bottom part of the Figure 1 (d) shows the visual hint, which identifies a pattern of three smaller triangles in the shaded area, by moving and flipping the triangle at the bottom (d). Thus, only one triangle area needs to be computed and multiplied by three. In a different problem, Figure 1(e), a visual hint suggests that the student mentally invert the cut-out portion of a drawing to reveal the intact rectangle, suggesting that the missing lengths are already known.

Fantasy component

The ultimate goal of this tutor is to enhance students' conceptual understanding of mathematical concepts, and their ability to draw on their skills to solve novel problems. Therefore, Wayang Outpost also incorporates fantasy adventures that present challenging mathematical problems requiring multiple steps and skills to solve. These adventures incorporate real-world content. Animated characters, based on real female scientists (who serve as role models) lead the virtual adventures, Figure 2. This fantasy component is female-friendly and uses female role models. For example, the character based on Anne Russon of York University, an expert on the orangutan, invites students to rescue orangutans trapped in a fire in the rainforest Figure 2 (a and b). She takes students across the rainforest and uses geometry skills to calculate the shortest path. Performance on the fantasy component becomes a measure of transfer of math skills from SAT problems to a different context where the same mathematics skills are needed to solve problematic situations, such as calculating shortest paths, determining if a jeep can safely ride across a broken bridge, based on the fact that the jeep can withstand a certain falling height, Figure 2 (b).

The character based on Lori Perkins leads an adventure investigating illegal logging, which involves the over-harvesting of rainforest teakwood, flooding and loss of orangutan habitat, Figure 1 (d and e). Students are asked to calculate a variety of items: discrepancies between the observed and permitted areas of harvest; orangutan habitat area lost to the resulting floods; perimeter distances required to detour around flooded areas; and how far it is to travel to reach areas with emergency cell phone access using cone models of satellite coverage. Within the fantasy adventure students are provided with hints and shown SAT problems with multimedia help that are similar to the problem being solved within the adventure. Fantasy problems, such as these are motivating and engaging. They entertain students (almost like a video game) and students did not feel they were a burden.

Evaluation Results

The tutor was evaluated through several studies carried out in rural and urban area schools in Massachusetts (Walles, 2005). In each study, students were randomly assigned to two different versions of the system: one providing spatial help, the other providing computational help. A third (control) group took the pre- and post-test but did not use the tutor. Instead, they were engaged in regular mathematics classroom activities instead of using Wayang. Students took a computer-based mental rotation test (Vandenberg et al., 1978) and a computer-based test that assessed a student's speed and accuracy in determining whether simple mathematics facts (such as 5x4=20) were true or false (Royer et al., 1999). The study involved over 200 students, with complete pencil and paper pre- and post-tests. Students used the tutor in this way for about two hours.

The SAT geometry domain turned out to be quite difficult for students; they did not do particularly well on the problems. On average, students correctly answered less than 25% of the pre-test items. Students' spontaneous comments also reinforced the impression that the domain was very difficult, as did their active use of multimedia help while working with the tutor. On average, students entered only one incorrect answer before requesting help. This suggests that, for the most part, they were not randomly clicking answers until they stumbled on the correct response, but were actively trying to learn problem-solving strategies.

Students did learn from the tutor, despite the difficulty of the domain. Students who used the tutor improved, and only on tutored (geometry) skills. Their scores improved significantly from pre- to post-test ($M = .35$ and $M = 3.34$, respectively). This finding helps to eliminate the possibility that observed benefits associated with a tutor might reflect the general novelty of working with a computer. Students in the control group did not improve from pre- to post-test. Thus, the improvement associated with the tutored students cannot be attributed to increased familiarity with the test format, or learning from taking the pre-test. The tutor intervention group did not significantly improve on the non-tutored algebra problems, and the control group did not improve from pre- to post-test on either question type.

In addition to pre- and post-test scores, we considered the impact of the tutor on students' willingness to attempt unfamiliar and challenging math problems. Paired sample comparisons revealed a significant *increase* in the percentage of correct questions from pre- to post-test, a significant *decrease* in the percentage of skipped questions and *no significant change* in the percentage of incorrect questions. In order to gauge the Wayang tutor's effectiveness in tutoring students of varying ability, students were divided into groups based on their pre-test scores using a median split technique, e.g., (low scorer/high scorer). There was a significant interaction between pre-test rating and pre- to post-test performance. Students who performed poorly on the pre-test showed a significant improvement from pre- to post-test. Students with weaker skills benefited the most from the tutor. These students also made more use of the help features in the tutor. Again, this is the reverse of the usual findings in the regular classroom, in which higher achieving students are most likely to request help from teachers and classmates. In the private context of the tutor environment, students with weak skills seem comfortable requesting help and instruction, and their performance improves accordingly. This finding is relatively unusual in K-12 research in which, most frequently, interventions have the greatest benefit for those students who were already doing well to begin with ("the rich get richer" effect). Those who received higher scores on the pre-test showed no significant change from pre- to post-test.

There appeared to be a trend by which males ($M = 85.17$) asked for more help than their female counterparts ($M = 63.12$). Royer et al. (1999) noted that male students show a bimodal distribution: the best students are more often male, but so are the worst performing students. Researchers have noted that some students use help features to search for the correct answer and it appears that males may be more likely to do this than females.

There were suggestions that students found the visual help more useful or engaging. Students in the visual condition ($M = 11.10$) viewed more mode-specific hints than their counterparts in the analytic condition ($M = 7.11$). There was a main effect of multimedia help type with respect to the number of problems where all help was seen before a correct answer was given. Specifically, those in the visual condition ($M = 13.90$) had a higher number of this type of problem than those in the analytic condition ($M = 10.75$). There was a consistent trend whereby those in the visual condition viewed more help than those in the analytic condition. Because students had to request help step-by-step, this finding suggests that the visual help may be more intriguing than the more traditional analytic help. Perhaps students were more attracted to the visual help since its strategies are not often presented in the classroom (Aleven, 2001). Surprisingly, females significantly outperformed their male counterparts on the measure of math-fact retrieval accuracy. Controlling for all other variables, math-fact retrieval score and pre-test score were both significant predictors of post-test performance. Specifically, higher math-fact retrieval scores and pre-test scores were individually associated with higher post-test scores. Students attempted more items on the post-test, suggesting that they learned enough to at least try to tackle the challenging items, but were not yet necessarily prepared enough to answer them correctly. Clearly, it will be important to provide students with enough tutoring to ensure that their greater confidence is matched by the required skills.

Conclusions

We described Wayang Outpost, a tutoring system that uses multimedia and customization of problems based on knowledge of cognitive skills and gender. The tutor taught the mathematics section of the Scholastic Aptitude Test, used by students in high schools of the U.S.A. We described how we are adding intelligence for adaptive behavior in different parts of the system. The tutor was extremely beneficial for students in general, with high improvements from pre to posttest. Girls were especially motivated to use the fantasy component and some studies showed that adapting the hints to students' basic cognitive skills can yield higher learning results.
Future work to improve student learning involves two approaches. First, we are using machine learning to identify ways to customize problems and hints based on knowledge about previous students. Currently Wayang Outpost customizes the problems and hints using fixed algorithms or rules of student behavior. Thus the tutor has an algorithm that treats equivalently all students who fall into the same classification cells, based on pre-tests and behavior with the tutor. The tutor does not improve over time. We are incorporating the interactions of previous users by creating a data-centric student model that enables the system to predict student performance and enhance learning (Beck et al., 2000; Mayo & Mitrovic, 2001). Machine learning is now modeling prior student behavior, to learn which pedagogical strategies are effective and to develop new and more powerful strategies. Optimization is directed at reducing a student's time to achieve mastery within the curriculum.

Our second approach to improving student learning is to evaluate the impact of cognitive skills training on students' achievement with the tutor. We intend to investigate whether training spatial abilities (with a tutoring system that trains mental rotations with 3-dimensional cubes) or training math fact retrieval speed (with exercises that help a student memorize arithmetic facts) helps improve performance with the tutor and/or learning with different teaching strategies that capitalize on these basic cognitive skills. This work advances the state-of-the-art in both knowledge-based learning environments and multimodal interfaces. By achieving significant gains in learning effectiveness, the combination of these technologies can bring about fundamental improvements in learning both for students in the classroom and those working alone.

Acknowledgements

We gratefully acknowledge support for this work through two awards from the National Science Foundation, 1) HRD/EHR #012080, Beal, Woolf, & Royer, "AnimalWorld: Enhancing High School Women's Mathematical Competence." and 2) Learning to Teach: The Next Generation of Intelligent Tutor Systems, B. Woolf, P.I., with A. Barto, D. Fisher, S. Mahadeva and I. Arroyo, co-P.I.s NSF REC ROLE, # 0411776, 08/15/2004-08/14/07; Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the granting agencies.

References

Aleven, V. (2001). Helping Students to Become Better Help Seekers: Towards Supporting Meta-cognition in a Cognitive Tutor. Paper presented during a workshop organized by the NSF/DFG-sponsored German-USA Early Career Research Exchange Program: Research on Learning Technologies and Technology-Supported Education, Tübingen, Germany.

Arroyo, I. (2003). Quantitative evaluation of gender differences, cognitive development differences and software effectiveness for an elementary mathematics intelligent tutoring system. Doctoral dissertation.

Arroyo, I., Beck, J., Woolf, B., Beal, C. & Schultz, K. (2000). Macroadapting Animalwatch to gender and cognitive differences with respect to hint interactivity and symbolism. *Proceedings of the Fifth International Conference on Intelligent Tutoring Systems*.

Beal, C. & Arroyo, I. (2002). The AnimalWatch project: Creating an intelligent computer mathematics tutor. In S. Calvert, A. Jordan, R. Cocking (Eds.), *Children in the digital age*. Greenwood.

Beal, C., Beck, J., Westbrook, D., Atkin, M. & Cohen, P. (2002). Intelligent modeling of the user in interactive entertainment. Paper presented at the AAAI Stanford Spring Symposium, Stanford CA.

Beck, J., Woolf, B & Beal, C. (2000). ADVISOR: A machine learning architecture for intelligent tutor construction. In the *Proceedings of the Seventeenth National Conference on Artificial Intelligence*.

Brown, A. L., Ellery, S. & Campione, J. (1994). Creating Zones of Proximal Development Electronically. In J. Greeno & S. Goldman (Eds.), *Thinking practices: A symposium in mathematics and science education*. Hillsdale NJ: Erlbaum.

Casey, N. B., Nuttall, R. L. & Pezaris, E. (1997). Mediators of gender differences in mathematics college entrance test scores: A comparison of spatial skills with internalized beliefs and anxieties. *Developmental Psychology*, *33*, 669-680.

Casey, N.B., Nuttall, R., Pezaris, E. & Benbow, C. (1995). The influence of spatial ability on gender differences in math college entrance test scores across diverse samples. *Developmental Psychology*, *31*, 697-705.

Ericsson, K. A., Krampe, R. T., Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Graesser, A, VanLehn, K., Rose, C., Jordon, P. & Harter, D. (2001). Intelligent Tutoring Systems with Conversational Dialogue, *AI Magazine, American Association for Artificial Intelligence*, 22(33), Winter: 39-51.

Greenfield, P.M. & Lave, J. (1982). Cognitive aspects of informal education. In D. Wagner & H. Stevenson (Eds.), *Cultural perspectives on child development* (pp. 181-207). San Francisco: Freeman.

Johari, A. (2003). Effects of Inductive Multimedia Programs In Mediating Word Problem Translation Misconceptions, *Journal Of Instructional Psychology*, March.

Kaput, J. (1992). Technology and mathematics. In D. A. Grouws (Ed.), Handbook of research on mathematics and learning (pp. 515-556). New York: Macmillan.

Koedinger, K.R., Anderson, J.R., Hadley, W.H. & Mark, M.A. (1997). Intelligent tutoring goes to school in the big city, *Int'l Journal of Artificial Intelligence in Education, 8*, 30-43.

Lepper, M. R., Woolverton, M., Mumme, D. & Gurtner, J. (1993). Motivational techniques of expert human tutors: Lessons for the design of computer-based tutors. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools*, pp. 75-105. Hillsdale NJ: Erlbaum.

Lester, J., Converse, S., Stone, B., Kahler, S. & Barlow, T. (1997). Animated Pedagogical Agents and Problem-Solving Effectiveness: A Large-Scale Empirical Evaluation. *Proceedings of the Eighth World Conference on Artificial Intelligence in Education*, pp. 23-30, Kobe, Japan.

Marinello, M. & Cook, G. (2000). *Interdisciplinary Inquiry*. Upper Saddle River, NJ: Prentice-Hall.

Mayer, R. E. (2001). *Multimedia Learning*. New York: Cambridge University Press.

Mayo, M. & Mitrovic, A. (2001). Optimising ITS behaviour with Bayesian networks and decision theory, *IJAIED, 12*(2), 124-153.

Royer, J., Tronsky, L., Chan, Y., Jackson, S., & Marchant, H. (1999). Math-fact retrieval as the cognitive mechanism underlying gender differences in math test performance. *Contemporary Educational Psychology, 24*, 181-266.

Royer, J., Tronsky, L., Marchant, H., & Jackson, S. (1999). Reply to the commentaries on the math-fact retrieval hypothesis. *Contemporary Educational Psychology, 24*, 286-300.

Shute, V. (1995). SMART: Student Modeling Approach for Responsive Tutoring. In *User Modeling and User-Adapted Interaction,* 5, 1-44.

Vandenberg, G. S. & Kuse, R. A. (1978). Mental Rotations, A Group Test of Three-Dimensional Spatial Visualization. *Perceptual and Motor Skills*, *47*, 599-604.

Walles, R. (2005). Effects of Web-Based Tutoring Software on Math Test Performance: A Look at Gender, Math-Fact Retrieval Ability, Spatial Ability and Type of Help. Master's Thesis, University of Massachusetts, Department of Psychology.