Towards Designing a User-Adaptive Web-Based E-Learning System

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Abstract
This work-in-progress report presents the groundwork for the design of a user-adaptive web-based e-learning system. A survey and two randomized controlled experiments were carried out to compare the effects of active versus passive interaction on attitude and learning and to compare user vs. system initiated control of information presentation. Results showed that the more time-consuming active interaction was indeed more helpful to less-proficient students, but it was not as helpful to more-proficient students. Results also indicate that both more- and less-proficient students learn more from system initiated information presentation. These results will help to design a user-adaptive e-learning system that can determine which kind of interactivity and information presentation works best for which students and when.

Keywords
E-learning, user-adaptive systems, user/system initiative, information presentation

ACM Classification Keywords
H5.2 Information interfaces and presentation (e.g., HCI): User Interfaces – Evaluation/Methodology; H1.2

Models and Principles: User/Machine Systems- Human Information Processing.

Introduction

Learning and assessment supported by technology is becoming more widespread and the effectiveness of the pedagogy of these applications is an active area of research. The focus on the intersection of HCI and e-learning systems and how to engage users, keep them motivated and encourage them to interact with these applications in a learner oriented manner that stimulates deep learning is more recent.

It has been observed that students often use learning technologies in a "performance-oriented" manner trying to get through more material quickly instead of in a "learning-oriented" manner with the purpose of learning as much as possible [2]. When tutoring a student, a tutor needs to decide whether to give a complete explanation on a topic or whether to draw out the explanation from the student through questions and interactive dialog. A question of interest is whether more interactive one-to-one dialog between students and tutors will result in more learning-oriented behavior, and thus more learning, than less interactive methods such as presenting the same information without expecting the student to interact with it.

There are several arguments for stressing interactivity in e-learning applications. Students must pay closer attention when they are expected to participate and contribute to the tutoring session so they are less likely to daydream or skip over relevant material. The tutor can also identify misunderstandings or gaps in knowledge that the student may have and address them.

Background

According to VanLehn et al. [11], the *interaction hypothesis* is as follows: "When one-on-one natural language tutoring, either by a human tutor or a computer tutor, is compared to a less interactive control condition that covers the same content, then the tutees will learn more than the nontutees." (This research does not deal with natural language tutoring, but is concerned with learning technologies that engage the student by using multiple choice, fill-in-the-blank and pull-down menu questions.)

Several studies in the literature have found evidence to support the interaction hypothesis with human tutors. When comparing Socratic and didactic tutoring strategies, it was found that the more interactive (based on the number of words produced by students) Socratic tutorial dialogs had greater correlations with learning, where students who engaged in a more interactive style of human tutoring could transfer their knowledge better than the students in the didactic tutoring condition [3, 4]. Similar results that support the interaction hypothesis have been found in studies of interactive learning technologies [5].

It appears that a positive relationship between learning and tutor interactivity exists, and we would expect students to learn more whenever they engage in more interactive tutoring conditions than in less interactive conditions such as reading text. There is, however, evidence that this is not always the case. VanLehn et al. [11] reviewed studies that appear to support the interaction hypothesis as well as studies that did not support the interaction hypothesis with both human tutors and learning technologies. We are interested in determining when the relationship between interactivity and learning is positive and when interactivity has little effect on learning.

Two randomized controlled experiments were carried out to determine if and when interactive tutoring strategies help students to learn more. In these experiments, we compared active versus passive interaction and user versus system initiated information presentation. Students were surveyed to determine their attitudes about the e-learning system and these strategies.

Methodology

A web-based e-learning system was built to integrate assistance and assessment by offering instruction to students while providing a detailed evaluation of their abilities to teachers [8]. This system, dubbed the ASSISTment system, tutors students on problems taken from the Massachusetts state test and is used by thousands of middle school students in central Massachusetts as part of their mathematics instruction.

Experiment 1

The purpose of Experiment 1 [7] was to compare the effects of active versus passive interaction on learning and to compare user vs. system initiated control of information presentation. In the active, system initiated condition, users were automatically presented with scaffolding questions when they made an error which they were required to answer before proceeding. In the passive, user initiated condition, users could request help in the form of hints that they do not actively respond to. We hypothesized that students would be more engaged in the active, system initiated condition and would learn more.

We chose to focus on problems that involved interpreting linear equations, which according to data from within the ASSISTment system, students found difficult. Four problems were chosen for the experiment and four more were chosen as transfer items to test whether the students had learned from the experiment. Two of the transfer items were also presented at the beginning of the experiment to serve as pre-test items so a gain score could be calculated. Students who got both pre-test items correct did not participate in the experiment as they probably had already mastered the material. Students who got a pre-test item wrong were not told the answer or given any tutoring on the item.

To make sure that all of the students had the opportunity to complete the transfer items, we timed the students during the experiment. The students were given 20 minutes to work on an assignment containing the two pretest items and four experiment items. They were then given 15 minutes to complete the four transfer items.

Figure 1 shows a problem used in the experiment. The column on the left, in the active condition, shows that a student has answered incorrectly and is immediately presented with a scaffolding question. The column on the right, in the passive condition, shows that a student got the item wrong and received the message, outlined in red, of “Sorry, that is incorrect”. The hint shown outlined in green appears when the student requests a hint by pressing the Hint button. As shown in Figure 1, the information presented in both conditions was the same so that one condition did not have an unfair advantage over the other. The difference is that the students in the active, system initiated condition were forced to give answers to the individual steps in the

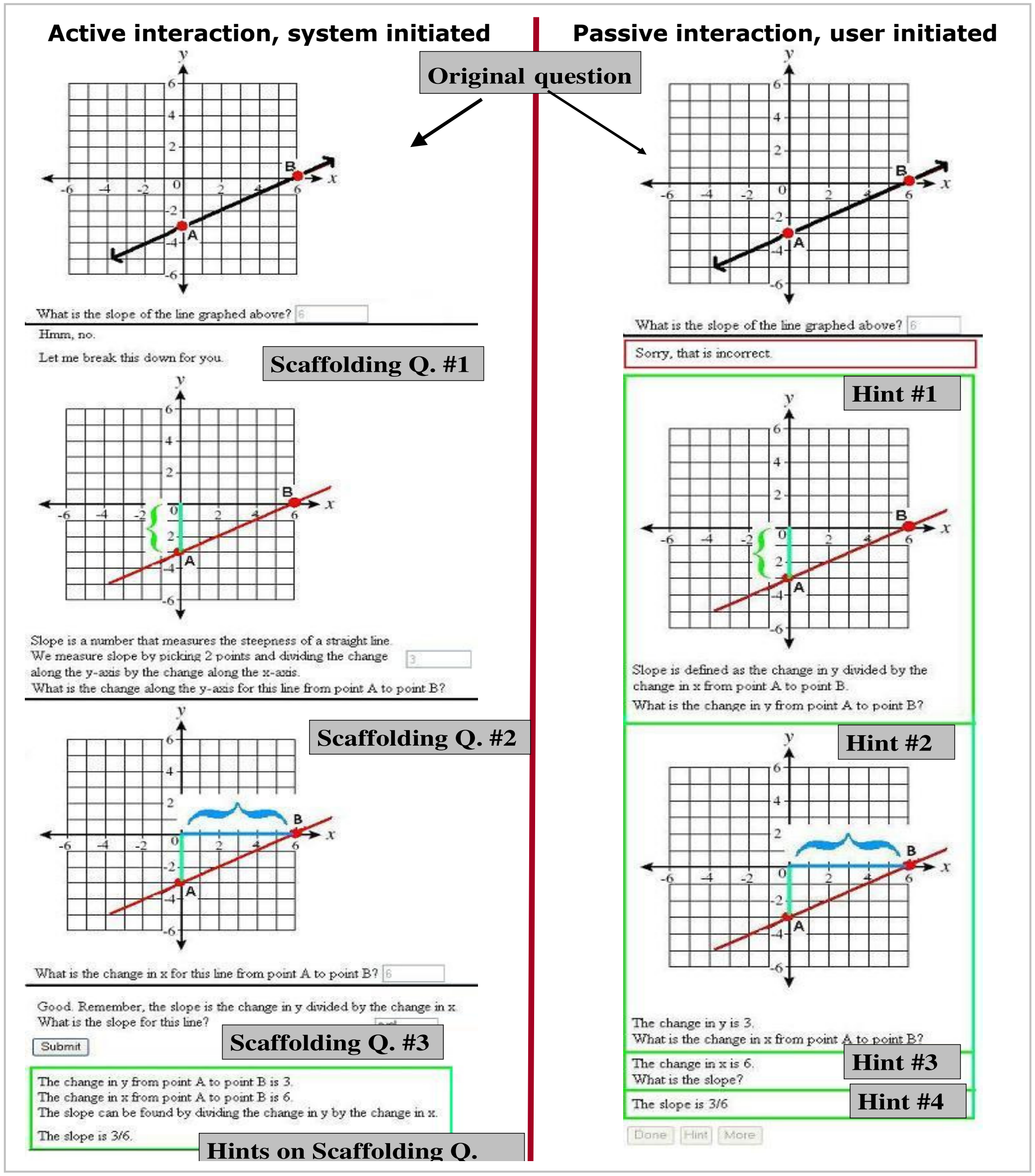

Figure 1. The two conditions of Experiment 1.

problem. We hypothesize that if there is a difference between conditions in this experiment it will be due to forcing students to work actively to solve a problem, i.e. learning by doing, rather than allowing them to be passive.

174 students from 3 middle schools in Worcester, Massachusetts participated in the experiment. The results indicated that there is more learning with system-initiated, active interaction than with user-initiated, passive interaction, and the difference in learning was significant ($p < 0.01$) between the two conditions when problems were difficult (based on pre-test scores). These results prompted us to study the link between the difficulty of the material and the effect of active vs. passive interaction and user vs. system initiated information presentation.

Experiment 2

Experiment 2 [6] compared three different conditions. In addition to the conditions of Experiment 1, system-initiated, active interaction and user-initiated, passive interaction, a third condition was introduced: system-initiated, passive interaction. In this new condition, the system presents students with solutions to each problem after they finish the assignment. The math proficiency of the students was also taken into consideration in Experiment 2 by looking at their pre-test scores and whether they were in honors math classes.

The procedure was similar to that of Experiment 1. 366 eighth grade students participated in this study and we found a significant interaction ($p < 0.05$) between the level of interactivity and the math proficiency of the student. Less proficient students benefited most from the active, system initiated condition and more proficient students benefited most from the passive, system initiated condition. This suggested that students using the ASSISTment system should benefit if the system could adapt its tutoring according to the level of math proficiency of the student.

Survey results

In 2005, 8th grade students who had used the ASSISTment system in their math classes during the school year were asked to complete a survey on their attitudes about math and the ASSISTment system. 324 students participated in the survey where they were asked to rate their opinions on the ASSISTment system and math in general.

Over 60% of the students surveyed thought that the ASSISTment system helped them prepare for the Massachusetts state test. Students who liked using the ASSISTment system better than normal classroom activity were positively correlated to standardized test scores.

Students who said they tried to get through difficult problems as quickly as possible were negatively correlated with learning during the course of the year. We believe that this falls in line with the results of Experiment 1 and Experiment 2. When problems were difficult, students who were in the passive interaction condition could finish items significantly faster but learned less; students who were in the active interaction condition were forced to spend more time doing scaffolding and ended up learning more. Students who thought that breaking a question down into smaller steps did not help them understand how to solve similar problems was negatively correlated with standardized test scores.

Future Directions

To date, we found that whether students benefited from active versus passive interaction depended on their math proficiency. Students also seemed to benefit more from system initiated information presentation regardless of their math proficiency. The focus of future analysis will be on further classifying the best information presentation strategies given the math proficiency of a student and using results to design a user-adaptive tutoring system.

Numerous e-learning systems that use adaptive help, feedback, and sequencing have been developed. Piagetian tests and Bayesian networks [1, 9] have been used to determine students' cognitive abilities and background knowledge for adaptive sequencing which chooses the next best problem for students to work on. Item Response Theory models [10] have been used to adapt help to students' ability by making hints more explicit with step-by-step instructions for low ability students and more conceptual for high ability students.

Our approach will be to use performance on pre-tests and performance within the system to determine students' proficiency and adapt the interactivity to individual students. Students will be able to see exactly the same information to help them solve a problem, but how they interact with it will adapt to their performance.

Conclusion

Results of this work can bring new focus to the intersection of HCI and e-learning systems by helping to inform the design of systems that are more effective in engaging the student to maximize learning results. This becomes more pertinent as teachers are expected to cover more material to address all of the topics covered in standardized tests, instructional time becomes more precious and teachers want to know that the interventions that they are using in their classrooms are effective for students of varying abilities.

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