PROOF-OF-CONCEPT OF AN AUGMENTED REALITY APPLICATION IN DEVELOPMENTAL MATHEMATICS

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Abstract

In this paper, we describe a new technological method, Augmented Reality Algebra, for developmental mathematics recitation. Our method, never before used in a developmental mathematics setting, relies on an interactive presentation of material via a simulated augmented reality environment. We describe our study, in which a simulation of this method was used on experimental groups of students. The resulting data is compared with related control groups, and some basic comparative statistical analysis is described. Our conclusion is that our students show significant improvement with the use of simulated Augmented Reality Algebra, when compared to students who learn and practice the same mathematics with more traditional approaches.

Introduction

In 2008, Strong American Schools reported that 43% of all students at public two-year universities have enrolled in a remedial course. In addition to this, the Maryland Higher Education Commission (MHEC, 2010) reported that about 65% of recent Maryland high school graduates enrolled in a developmental mathematics course at Maryland community colleges during the 2008-2009 school years. Developmental mathematics courses are gatekeeper courses that are essential in determining students' success in degree attainment (Fike & Fike, 2008). Therefore, it is important that students experience success in developmental mathematics so that they continue to the next level.

This quantitative study was designed to examine the effects of hands-on technology as a learning strategy to improve students' success in developmental mathematics. Using animated PowerPoint presentations as a hands-on instructional tool for students to learn algebra, we simulate a potential augmented reality environment that guides students through the recitation process. Ultimately our goal is to produce a legitimate enhanced augmented reality environment that we'll call Augmented Reality Algebra (ARA). Henceforth we will refer to the proof-of-concept current simulation of this environment as *simulated* ARA, or SARA. Augmented reality applications have been shown to improve the success of robotics applications; thus, the main research hypothesis in this study is that SARA is positively related to the success of developmental students.

Background

The content covered in developmental mathematics courses reflects mathematics topics students should have learned between grades K through 12. Therefore, it is important for developmental mathematics students to develop and employ learning strategies that will help them retain this content and be successful in their mathematics courses. Students need to learn mathematics with understanding and this can be accomplished through active engagement in mathematical tasks (National Council of Teachers of Mathematics [NCTM], 2000). Technology is also essential in learning mathematics; it enhances mathematics learning through visual models, instant feedback, and focused tasks (NCTM, 2000). Technology is an important tool that can be used to enhance learning for developmental mathematics students because technology can be designed to be "sensitive and responsive to the individual differences and special needs among learners" (Cassaza, 1999). Hence, it is necessary for researchers and practitioners, particularly at the community college level, to design, implement, and evaluate learning strategies that use technology to meet the needs of the developmental mathematics student.

Recently, there has been a major push for course redesign in higher education by the National Center for Academic Transformation (NCAT). One of the models of course re-design is the replacement model. In this model, some in-class instruction time is replaced with time doing interactive learning activities (NCAT, 2005). Technology can provide students with interactive learning materials that provide them with individualized instruction and an opportunity to adjust their learning progress (Twigg, 1999). The purpose of this study is to determine the effectiveness of SARA on the academic performance of students in algebra. The research questions for this study, which are certainly related, are: 1) does SARA improve students' performance in developmental mathematics, both short-term and long-term? 2) Does SARA help to reduce initial learning anxiety and improve confidence of students, allowing them to move on to the next level?

Description of Method

In this study, our attempt is to simulate a tutor helping a student. Students can interact with simulated augmented systems to practice procedures of basic mathematics problems to build a *habit-of-mind*, that is, a learned and reinforced pattern of effective habits and strategies for solving remedial mathematics problems. In a real-life situation, a student would start working on a problem in a tutoring center. As she starts the problem, she may or may not know how to proceed to the next step. If she can proceed, the tutor may then reply with positive encouragement, and provide some sort of confirmation that the student understands the problem. If the student is unable to proceed, the tutor might suggest the next step, wait to see if the student can follow through, and continue by leading her through this next step. At the developmental level, students thrive on this method of constant positive reinforcement and frustration reduction. However, the cost is high to help a student through the same type of problem many times over. But as we know, repetition is fundamentally important in learning, and especially so at this developmental level. For these students, doing similar problems again and again can help them feel very comfortable with the basic concepts, and enhance their confidence. But more importantly, these habits-of-mind that a student develops by doing these kinds of practice drills will help them later with more advanced concepts.

Our proposed plan for the implementation of SARA is the following. Students will work on a previously fixed set of problems. These problems will be programmed into a PowerPoint slide show, along with step-by-step solutions. As the student works on her problem at a desk, simultaneously a mini-projector will display the step-by-step solution to the problem directly onto the student's desk, accompanied by pre-recorded voice prompt. The solution steps will be displayed very slowly, with a predetermined delay between each step. The goal of this delay is to encourage the student to start - and continue - solving the problem independently. If she's unable to proceed, the next slide will be displayed to provide her with the next step. The rate of the slide animation is important: the slides should be displayed quickly enough to prevent the student from growing frustrated, but slowly enough to allow her to first attempt each step on her own.

In Spring 2011, we launched a small-scale preliminary study to assess the concept of using SARA in developmental mathematics courses. An animated PowerPoint presentation showing how to graph a straight line was developed. The presentation included examples of graphing a straight line when the equation of the line is given in three different forms: (1) $y = mx + b$; (2) $ax + by = c$; and (3) $a(x + b) = cy - d$. The preliminary study was conducted as follows. A lecture on how to graph a straight line using the slope-intercept form was presented to students in two class groups: Group A and Group B. Ten volunteering students from Group A and ten volunteering students from Group B were given practice problems that were similar to the examples in the lecture. Group A students worked on the practice problems with the help of the animated PowerPoint presentation, and Group B students worked on the practice problems without the help of the animated PowerPoint presentation.

The execution of SARA in these preliminary studies differs from our description of SARA above in three details: 1) the solutions revealed to the student were for similar – and not identical – problems, 2) the rate of animation was not automatic, but was controlled by the instructor (this helped us to calibrate the most effective rate of slide animation for future studies) and 3) the slides were projected by an overhead projector to the front of the classroom, and not onto the students' desks.

Group A (experimental):
Ten practice problems were given to the students in Group A. As the students worked on the practice problems, the animated PowerPoint presentation showing how to solve similar problems was running in front of the students. Students followed the steps shown in the animated presentation on an as-needed basis. The animation for each problem in the presentation was about 3-4 minutes long. Group A students spent 50 minutes on the set of practice problems.

Group B (control):
The students in Group B worked on the same 10 practice problems as the students in Group A, but the students in Group B were not provided with the animated presentation. The students in Group B did their practice problems in the usual manner. That is, the students in Group B referred to their books/notes to review the process of graphing a straight line. Group B students were also given 50 minutes to complete the set of practice problems.

The students in both sections were then quizzed on how to graph a straight line using the slope intercept form in their next class meeting. The students' scores in both sections were recorded and compared. As shown in the Table below, the performance of students in Group A was significantly better than the performance of students in Group B. A longitudinal study was also conducted to assess the students' retention of the knowledge and skills required to graph a straight line. A test (given two weeks later) and the department final exam (given 10 weeks later) contained problems related to graphing a straight line. As shown in Table 1, the performance of students in Group A was significantly better than the performance of students in Group B on both the test and the departmental final exam.

Table 1: Proof-of-concept study outcomes Spring 2011

	Group A (With ARA)	GroupB (Without ARA)	Improvement
Quiz (Given two days after the class)	The quiz was worth 20 points. Group A students as a whole earned 180 points out of 100 points (90%).	The quiz was worth 20 points. Group B students as a whole earned 140 points out of 100 points (70%).	22.2%
Test (Given two weeks after the class)	The relevant problem(s) on the test were worth 20 points. Group A students as a whole earned 176 out of 200 points (88%).	The relevant problem(s) on the test were worth 20 points. Group B students as a whole earned 126 out of 200 points (63%).	28.4%
Final Exam (Given at the end of the semester)	The relevant problem(s) on the test were worth 20 points. Group A students as a whole earned 168 out of 200 points (84%).	The relevant problem(s) on the test were worth 20 points. Group B students as a whole earned 10 out of 200 points (54%).	29.8%%

In Spring of 2012, we conducted another a small-scale study to assess the concept of using SARA in developmental mathematics courses. An animated PowerPoint presentation showing the solution of radical equations was developed. The presentation included examples of radical equations of different forms. The preliminary study was conducted as follows: A lecture on how to solve a radical equation was presented to students in a class section of 14 students. The class was split in two groups. Each group was randomly selected. Both groups spent 25 minutes on the practice problem set.

<u>Group A (experimental):</u>
As the students worked on the practice problems, the animated PowerPoint presentation showing the solution of the problems was running in front of the students. Students followed the steps shown in the animated presentation on an as-needed basis.

<u>Group B (control):</u>
This group did not have the animated presentation. Students in this group did their practice problems in the usual manner. That is, students in Section B referred to their books/notes to obtain the necessary information on how to solve a radical equation.

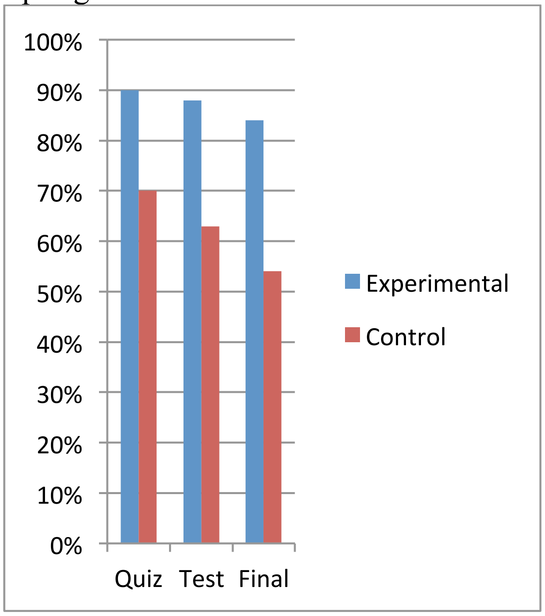
The students in both groups were then quizzed on how to solve a radical equation in the next class meeting. The students' scores in both sections were recorded and compared. The performance of students in group A was significantly better than the performance of students in group B. A longitudinal study was also conducted to assess the students' retention of the knowledge and skills. The test was given two weeks later and contained problems related to solving a radical equation. We did not measure students' performance in this topic in the final exam. As shown in Table 2, there was a significant improvement in students' performance in quiz and test following the study.

Table 2: Proof-of-concept study outcomes Spring 2012

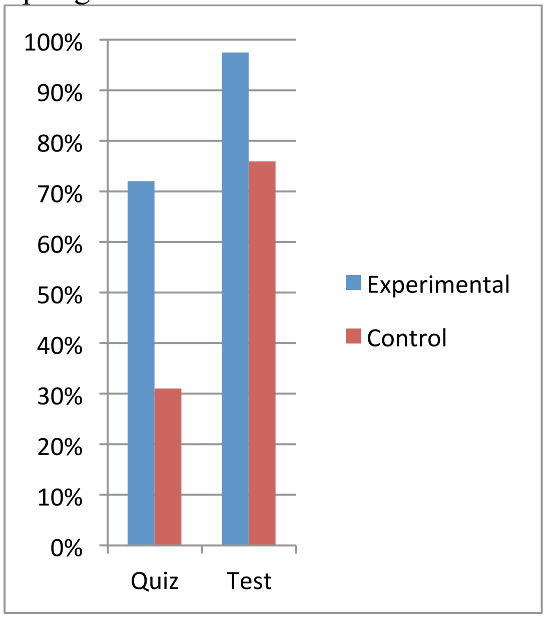
	Group A (With ARA)	GroupB (Without ARA)	Improvement
Quiz (Given 1 week later)	The quiz was worth 6 points. Group A students as a whole earned 26 points out of 36 points (72.0%).	The quiz was worth 6 points. Group B students as a whole earned 11 points out of 36 points (31.0%).	57.7%
Test (Given two weeks after the class)	The relevant problem(s) on the test were worth 8 points. Group A students as a whole earned 39 out 40 points (97.5%).	The relevant problem(s) on the test were worth 8 points. Group B students as a whole earned 30.5 out of 40 points (76.0%).	21.8%

Results:

Spring 2011



Spring 2012



The small-scale studies in 2011 and 2012 showed a strong correspondence between using SARA and the success of student in developmental mathematics classes. The test results of students using SARA compared to the students using traditional methods are compared. When SARA is employed, there is a 28.4% improvement and 21.8% improvement in these test results in Spring 2011 and Spring 2012, respectively. The implementations of SARA in 2011 and 2012 differed in one respect: in 2011, the problems displayed to students via the projector system were similar, but not identical, to the problems given to students. In 2012, the projected problems were identical to the problems solved by students. This difference may account for the significant improvement in *quiz* scores in 2012, as compared to 2011; the *test* scores did not follow this trend. The decrease in improvement in test scores using SARA from 2011 to 2012 may be a purely statistical artifact, as the sample sizes of students were quite small and therefore may result in some random fluctuation of improvement levels. The overall reaction from students using SARA was positive, although not uniformly so. Comments from the students included the following:

- It is easier to remember the steps as I can replay the movie in my mind.
- It is frustrating because I have to look down on my paper and up at the slide.
- Seeing the steps as I solve the problems is helpful.

Next Steps:

A larger scale of proof-of-concept study on SARA is necessary to rigorously confirm our results. In the fall 2013 semester, we will run another SARA study on 4 basic algebra classes, each with a maximum enrollment of 25 students. We therefore hope for a larger sample size and some more statistically robust data. This implementation will also feature individual face-down desk projectors, as well as pre-recorded voice accompanied guidance.

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