EFFECTS OF ANIMATED AGENTS IN WEB-BASED INSTRUCTION ON MATHEMATICS: ACHIEVEMENT AND ATTITUDES TOWARD MATHEMATICS

By

ANIKA W. LODREE* JOI L. MOORE** JUAN E. GILBERT***

ABSTRACT

This paper summarizes a quantitative study of the effects of animated agents in web-based instruction (WBI) on mathematics achievement and attitudes toward mathematics in post-secondary education. Eighty-one college students who were enrolled in a core mathematic course at a doctoral/research-extensive university in central Alabama participated in this study. Using a pretest - posttest control group design model, the study verified that the presence of animated agents in WBI can improve postsecondary students' mathematics achievement and attitudes toward mathematics. In addition, the interaction of gender choice of the animated agent with several demographic factors did statistically affect attitudes toward mathematics. These findings can be used to better design, develop, and implement a web-based tutorial that promotes positive attitudes toward learning mathematics and long-term mathematics achievement in postsecondary mathematics.

Keywords: Animated agents, Mathematics education, Post secondary education, Mathematics achievement.

INTRODUCTION

Most post-secondary education students, regardless of their academic major, are now required to complete a core mathematics course (Simmons & Jones, 2005). Many of these students have not demonstrated the interest or ability to excel in mathematics and are apprehensive about enrolling in a mathematics course because of previous experiences in a mathematics class (Coben, O'Donoghue, & Fitzsimmons, 2000; Cohen, 2000). Thus, it has become very important to find or develop appropriate instructional design methods that can help to improve attitudes toward mathematics as well as mathematics achievement among those students who are not mathematically oriented. Multimedia usage, such as, computers, audio, animation, animated agents, and video, in educational technology has the potential to offer a mathematical learning environment that is more effective and enjoyable (Kulik & Kulik, 1991). However, inclusion of media does not guarantee satisfactory learning outcomes (Moore, Burton, & Myers, 2004).

Technological advances, such as web-based course management systems and animation, have made web-based instruction (WBI) an attractive option for providing interactive activities to promote positive learning environments. Not surprisingly, interest in using animated agents in WBI has increased exponentially to improve the attractiveness of WBI. Multimedia tools have become more accessible, and they have proven to be very effective in motivating students to learn and changing students' attitudes towards learning (André, Rist, & Müller, 1997; Barron, 2004; Bates, 1994; Johnson, Rickel, & Lester, 2000).

The purpose of this study was to determine the effects of animated agents on achievement in post-secondary mathematics education and attitudes toward mathematics. By focusing on college students who do not demonstrate the ability to excel in mathematics and are not intrinsically motivated to complete mathematical tasks, we can gain valuable information or knowledge that can assist with the design and development phases of effective tools that are beneficial to diverse learners.

Review of Literature

Animated Agents:

Animated agents are implemented in WBI and appear on the screen as "embodied characters and exhibit various types of human-like behaviors, such as speech, emotions, gestures and eye, head and body movements" (Dehn & van Mulken, 2000, p. 2). The appearance, voice, and ability to communicate ideas are some of the essential components for establishing a clear communication between the student and the instructor. This may, in turn, affect student attitudes toward the content and the instructional environment. Lester and Stone (1997) indicate that the *persona effect*, which is the presence of an animated agent in an interactive learning environment, can positively affect students' perceptions of how well they can learn in this environment.

Mathematics Achievement in Post-secondary Education:

Many students' mathematics achievement in post-secondary education depends on a myriad of factors such as K-12 mathematics experiences, attitudes towards mathematics, parental attitudes toward mathematics and procrastination (Byrnes & Miller, 2007). If students have a good K-12 mathematics experiences and have a positive attitude towards mathematics and learning, they are more likely to excel in postsecondary mathematics course (Gal & Ginsberg, 1994). Thus, in order for students to excel in any learning environment, they must have a positive attitude towards learning.

Attitudes toward Mathematics:

Before learning begins, students may already possess attitudes that may affect their ability and motivation to learn (Wlodkowski, 1999; Zahn, 1969). Attitudes can be formed at a young age and continue to manifest as we encounter positive and negative experiences along with cultural and social stereotypes. As with all types of learning, having a positive attitude can provide the necessary motivation and belief that we can achieve. For non-STEM (Science, Technology, Engineering, and Mathematics) students, they may experience a higher degree of anxiety or negative attitude when entering mathematics-related courses (Gal & Ginsberg, 1994). Thus, it is very essential to introduce instructional tools that promote attitudinal improvement, which will lead to better understanding and achievement.

Methodology

There were 81 college undergraduate students (23 males and 58 females) attending a doctoral/research-extensive university in central Alabama during the summer and fall semesters. Each participant was enrolled in a Pre-Calculus course that was offered by the Department of Mathematics and Statistics for non-STEM majors. Seventeen participants were enrolled during the summer semester, and the remaining 64 were enrolled during the fall semester. Seventy-nine percent of the participants were freshmen, 3.7% were sophomores, 8.6% were juniors, and 8.6% were seniors. Age of the participants ranged from 19 to 24 years.

In this study, *Adam*, a WBI system that offers various forms of instruction using animated agents with verbal audio (Gilbert, 2002), was implemented. In *Adam,* students receive instruction from an animated agent via verbal audio, graphics, text, animation and other web deliverable media. Figure 1 gives an illustration of a lesson module in *Adam*. The animated agent speaks to the student as if he was an instructor. The student views the lesson content in the frame on the right and reads along as needed. The student can also pause the animated agent, read the material and then restart the animated agent. The student has the ability to click the question mark button to type a question that is submitted to a real teacher. When the teacher responds, the student will then receive an email message with the answer.

Furthermore, in *Adam*, students have the ability to select the persona of their teacher. There is a smiley face button,

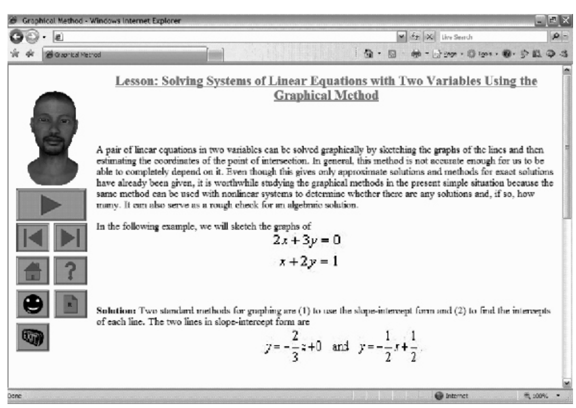

Figure 1. Snapshot of Adam Lesson Module

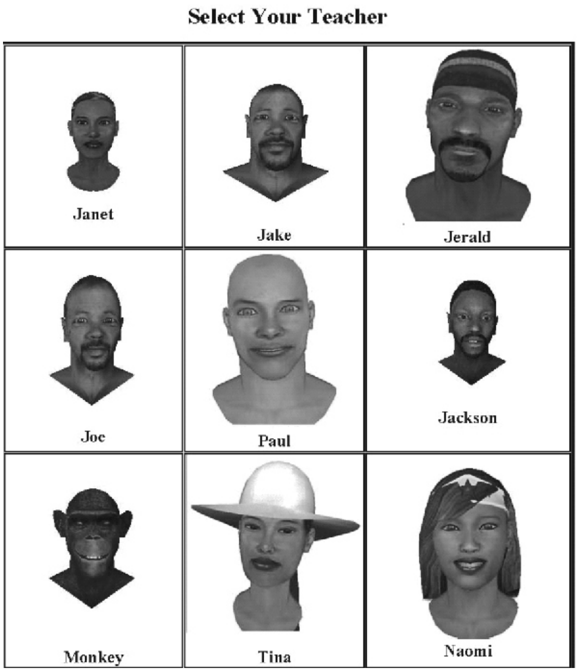

Figure 2. Snapshot of *Adam* - Teacher Selection

which represents the persona selection feature (see Figure 1). When a student clicks on the persona selection feature, s/he will be presented with the teacher selection screen (Figure 2). Each teacher, or persona, has a different physical appearance, voice and facial emotions (e.g. Some smile more than others). Each teacher delivers the exact same lecture for the same lesson content using his/her unique voice and facial emotions. Finally, at the end of each lesson module in *Adam*, the student is presented with an assessment. Assessments implemented in *Adam* are posted in web format using HTML forms.

For this study, students need not access *Adam* in the classroom, but can access it from any computer with Internet connection, during non-class hours with an Internet browser and a Haptek Player plug-in. (Haptek Player was used to display the animated agents (Haptek, 2008)).

In addition to the implementation of *Adam*, two lesson modules and assessment were created to test students' knowledge of i) solving quadratic functions and ii) graphing piecewise functions. Each module contained three problems and assessment related to the module content. Based on the teaching experience of one author, the content for the modules was chosen because most non-STEM majors tend to have difficulties with these topics in a Pre-Calculus course.

Data Collection Procedure

This study implemented a pretest-posttest control group design with matching:

Participants were grouped into pairs on the basis of their pre-assessment scores (Borg & Gall, 1989). The experimental group (n= 38) completed lesson modules using *Adam*, whereas the control group (n = 41) completed paper versions of the lesson modules without using *Adam*. Both groups had access to the same curriculum, materials, syllabus, exams, and a face-to-face learning environment, which was taught by different instructors.

The data collection process was divided into three stages:

Pre-assessment stage, lesson module completion stage, and post-assessment stage. The purpose of the pre-assessment stage was to gather mathematics achievement and mathematics attitudinal data before the introduction of *Adam* by completing a pre-lesson assessment activity (that corresponded to the lesson module) and the Sandman's Mathematics Attitude Inventory. As a homework assignment, each participant in the experimental group was asked to complete the lesson module using *Adam*, and each participant in the control group was asked to complete the paper-based version of the lesson module. At the completion of each lesson module, all participants completed a post-lesson assessment that corresponded with that module. Participants were allowed to ask their instructors questions pertaining to the lessons and *Adam.* Finally, the researchers used the attitudinal scale from the pre-assessment stage to gather attitude data after completing all the lesson modules.

The independent variables for this study were :

WBI using *Adam* and several demographic factors as college classification, gender, and WBI experience. To measure WBI experience, each student was asked if they ever enrolled in a course that utilizes WBI and/or

College Classification	(1) Freshman (3) Junior	(2) Sophomore (4) Senior
Gender	(1) Male	(2) Female
Enrollment in a course that utilized WBI	(0) Yes	(1) No
Completion Web-based course	(0) Yes	(1) No

Table 1. Transformation of Demographic Factors

completed a WBI course. Table 1 illustrates the transformation of the demographic factors.

The dependent measures for this study were:

The difference between post-and pre-mathematics lesson assessment scores and the difference of attitudes toward mathematics post - and pre-assessment scores. Furthermore, student performances on exam problems that were related to the content delivered via *Adam* were compared between the two groups. The lesson assessment scores measured immediate mathematics achievement, whereas, the average score of the exam problems measured the transfer of mathematical knowledge that pertained to the lesson modules.

Results

An one-way ANOVA that investigated the differences between the experimental group and the control group [see Table 2] showed that there were significant differences among both group when investigating mathematics achievement [F = 3.990, p < .05] and attitude change towards mathematics [F = 4.733, p < .05]. The experimental group significantly outperformed the control group on all lesson assessments, which measured immediate mathematics achievement. However, there existed no significant differences between the two groups when investigating the transfer of mathematics knowledge [F = .672, p > .05]. Thus, the two groups performed similarly on exam problems that were related to the content delivered through *Adam*.

To examine the effects of animated agents on mathematics achievement and attitudes towards mathematics based on gender, two-way ANOVAs were performed. Results of these ANOVAs [Table 3] showed that the main effects for gender [F = .002, p > .05], [F = .150, p > .05] and the interaction between gender and group type [experimental and control] [F = .327, p > .05], [F = .219, p > .05] failed to reach significanct differences in mathematics achievement and attitudes toward mathematics, respectively. This suggests that females are just as mathematically inclined as males. In addition, the experimental group experienced a positive change in their attitude towards mathematics, while the control group experienced a negative change.

When examining college classification and attitude change toward mathematics, the main effects for group type [F = 7.197, p < .05] reached statistical significance, while the main effects [F = .347, p > .05] and their interaction [F = .1.768, p > .05] failed to reach statistical significance [Table 4]. These results indicate that the level of attitude change towards mathematics was higher for students in the experimental group than for those in the control group. For college classification, the main effect

		Sum of Squares	df	Mean Square	F	Sig.
Mathematics Achievement	Between Groups	6.789	1	6.789	3.990	.049*
	Within Groups	132.708	78	1.701		
Attitude Change towards Mathematics	Between Groups	.385	1	.385	4.733	.033*
	Within Groups	5.046	62	.081		

*p < .05

Table 2. ANOVA Group Type Mathematics Achievement and Attitude Change towards Mathematics

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Immediate Comprehension	Group Type	7.094	1	7.094	4.080	.047*
	Error (Group Type)	132.708	78	1.701		
	Gender	.003	1	.003	.002	.966
	Group Type * Gender	.568	1	.568	.327	.569
	Error	132.140	76	1.739		
Transfer of Knowledge	Group Type	.733	1	.733	.704	.404
	Error (Group Type)	80.432	77	1.045		
	Gender	2.125	1	2.125	2.041	.157
	Group Type * Gender	.100	1	.100	.096	.757
	Error	78.073	75	1.041		

*p < .05

Table 3. ANOVA Gender by Group Type Mathematics Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.583	1	.583	7.197	.010*
College Classification	.084	3	.028	.347	.792
Group Type * College Classification	.286	2	.143	1.768	.180
Error	4.617	57	.081		

*p < .05

Table 4. ANOVA College Classification by Group Type Attitude Change towards Mathematics

shows that for the experimental group, the sophomore class experienced a slight improvement in their attitude towards mathematics, whereas for the control group, the freshman class experienced a slight improvement. There were no significant differences when examining college classification and mathematics achievement [Table 5].

The study also investigated how previous experience in courses that utilized WBI might affect attitudes [Table 6]. For the experimental group, students who had used WBI had a more positive attitude change in mathematics than those without WBI usage. The reverse was true for the control group wherein students with previous WBI experience demonstrated a more negative attitude change in mathematics than students without WBI usage.

		Type III Sum of Squares	df	Mean Square	F	Sig.
Immediate Comprehension	Group Type	.826	1	0.826	.472	.494
	College Classification	4.205	3	1.402	.802	.497
	Group Type * College Classification	3.333	3	1.111	.635	.595
	Error	125.901	72	1.749		
Transfer of Knowledge	Group Type	.011	1	.011	.010	.921
	College Classification	4.860	3	1.620	1.531	.214
	Group Type * College Classification	.299	3	.100	.094	.963
	Error	75.136	71	1.058		

*p < .05

Table 5. College Classification by Group Type Mathematics Achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.381	1	.381	4.576	.036*
Enrollment in Courses that utilized WBI	.022	1	.022	.261	.611
Group Type * Enrollment in Courses that utilized WBI	.028	1	.028	.335	.565
Error	4.993	60	.083		

* p < .05

Table 6. ANOVA Enrollment in Courses that utilized WBI by Group Type Attitude Change towards Mathematics

For completion of WBI courses, the attitude changes toward mathematics reached statistical significance [Table 7] for group type main effect [$F = 4.576$, $p < .05$], but not for WBI experience [$F = .261$, $p > .05$] and their interaction [$F = .335$, $p > .05$]. The change was higher for students in the experimental group than for those in the control group. However, there were no significant differences in mathematics achievement.

Finally, the interaction of gender choice of the animated agent by the student with one of demographic factors, college classification, did statistically affect attitudes toward mathematics [$F = 5.039$, $p < .05$]. Participants with freshman status who chose a female agent mathematically outperformed the other students with different classification status.

Discussion and conclusion

Results of statistical tests determined that the presence of animated agents in web-based mathematics education and positive reinforcement may have led to the improvement of students' attitudes toward mathematics and mathematics achievement. Students in the experimental group experienced positive changes in regards to their perception of their mathematics instructor, anxiety towards mathematics, the value of mathematics in today's society, self-concept of mathematics, enjoyment of mathematics, and

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.675	1	.675	8.468	.005*
Completion of WBI Courses	.028	1	.028	.348	.558
Group Type * Completion of WBI Courses	.307	1	.307	3.852	.054
Error	4.703	59	.080		

*p < .05

Table 7. ANOVA Completion of WBI Courses by Group Type Attitude Change towards Mathematics

motivation in mathematics whereas the students in the control group experienced negative changes in all the six areas. Finally, according to this study, the characteristics, such as gender and functions of the animated agents are important to consider when designing and developing a web-based mathematical virtual learning environment.

Based on this study, the presence of animated agents in a mathematical learning environment does have the capability to provide the enrichment and support that can make a student feel more comfortable and motivated to learn mathematics. Thus, the creation and implementation of a web-based mathematical learning environment that incorporates animated agents may lead to improvement in mathematics achievement and attitudes (Baylor & Kim, 2003). In conclusion, more non-math oriented students can attain the fundamental concepts and skills to be successful in their discipline.

Acknowledgements

The instructional design of *Adam* was supported under the National Science Foundation Grant #CNS-0296169. The views and conclusions contained herein are those of the authors and should not be interpreted as representing the official policies or endorsements, either expressed or implied, of the NSF, the U.S. Government, or any other organization.

References

[1]. André, E., Rist, T., & Müller, J. (1997, August). *WebPersona: A Life-like presentation agent for educational applications on the world wide web.* Paper presented at the Proceedings of the workshop "Intelligent Educational Systems on the World Wide Web," Eighth World Conference of the AIED Society, Kobe, Japan.

[2]. Barron, A. E. (2004). Auditory instruction. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 949-978). Mahwah, N.J.: Lawrence Erlbaum.

[3]. Bates, J. (1994). The role of emotion in believable agents. *Communications of the ACM, 37*(7), 122-125.

[4]. Baylor, A., & Kim, Y. (2003). *The role of gender and ethnicity in pedagogical agent perception.* Paper presented at the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2003, Phoenix, Arizona, USA.

[5]. Borg, W. R., & Gall, M. D. (1989). *Educational research: An introduction* (Fifth Edition). New York City, NY: Longman.

[6]. Byrnes, J.P. & Miller, D.C. (2007). The relative importance of predictors of math and science achievement: An opportunity-propensity analysis. *Contemporary Educational Psychology*, *32*(4), 599-629.

[7]. Coben, D., O' Donoghue, J., & Fitzsimmons, G. E. (Eds.). (2000). *Perspectives on adults learning mathematics* (Vol. 21). Norwell, MA: Kluwer Academic Publishers.

[8]. Cohen, D. (2000). Numeracy, mathematics, and adult learning. In I. Gal (Ed.), *Adult numeracy development: Theory, research, practice* (pp. 33-50). Cresskill, NJ: Hampton Press, Inc.

[9]. Dehn, D. M., & van Mulken, S. (2000). The impact of animated interface agents: A review of empirical research. *International Journal of Human-Computer Studies, 52*(1), 1-22.

[10]. Gal, I., & Ginsberg, L. (1994). The role of beliefs and attitudes in learning statistics: Towards an assessment framework. *Journal of Statistics Education, 2*(2), 1-18.

[11]. Gilbert, J. E. (2002). Playing teacher. *World Conference on E-Learning in Corp., Govt., Health, & Higher Ed. 2002(1)*. [On-line]. Available:http://dl.aace.org/9381.

[12]. Haptek. (2008). Haptek. Available: http://www.haptek.com

[13]. Jackson, C. D., & Leffingwell, R. J. (1999). The role of instructors in creating math anxiety in students from kindergarten through college. *Mathematics Teacher, 92*(7), 583-586.

[14]. Johnson, W. L., Rickel, J. W., & Lester, J. C. (2000). Animated pedagogical agents: Face-to-face interaction in interactive learning environments. *International Journal of Artificial Intelligence in Education, 11*, 47-78.

[15]. Kulik, C.-L. C., & Kulik, J. A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior, 7*, 75-94.

[16]. Lester, J. C., & Stone, B. A. (1997, February). *Increasing believability in animated pedagogical agents.* Paper presented at the Proceedings of the First Conference on Autonomous Agents, Marina del Rey, CA.

[17]. Moore, D. M., Burton, J. K., & Myers, R. J. (2004). Multiple-channel communications: The theoretical and research foundations of multimedia. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (pp. 979-1005). Mahwah, NJ: Lawrence Erlbaum.

[18]. Simmons, K., & Jones, A. (2005). UGA may toughen curriculum; Requirements, grades targeted. *The Atlanta Journal-Constitution, August 16*, 1B.

[19]. Wlodkowski, R. J. (1999). *Enhancing adult motivation to learn: A comprehensive guide for teaching all adults*. San Francisco, CA: Jossey-Bass Publishers.

[20]. Zahn, J. (1969). Some adult attitudes affecting learning: Powerlessness, conflicting, needs, and role transition. *Adult Education Journal, 19*(2), 91-97.

ABOUT THE AUTHORS

** Instructor in Mathematics and Statistics, Auburn University.*
*** Associate Professor, School of Information Science and Learning Technologies, University of Missouri - Columbia.*
**** TSYS Distinguished Associate Professor in Computer Science and Software Engineering, Auburn University.*

Dr. Anika W. Lodree is an Instructor in the Department of Mathematics and Statistics at Auburn University (AL) where she coordinates and teaches mathematics courses for elementary education majors. Dr. Lodree earned her doctorate in Information Science & Learning Technologies. Additionally, she assists future K-12 teachers with technology implementation. Current research interests include: Technology implementation in K-12 education and student diversity and retention.

Dr. Joi L. Moore is an Associate Professor in the School of Information Science & Learning Technologies at the University of Missouri where she manages and teaches courses in the Digital Media Curriculum. Dr Moore's current research interests include: Constructing knowledge in online learning environments; Addressing information architecture in Electronic Performance Support Systems and Interactive Learning Environments; and Designing user-centered web applications (Human Computer Interaction and Human Information Behavior).

Dr. Juan E. Gilbert is the TSYS Distinguished Associate Professor in the Department of Computer Science and Software Engineering at Auburn University. He has been named a Distinguished Speaker for the Association for Computing Machinery.