THE EFFECTS OF ANIMATED AGENTS WITH VERBAL AUDIO ON MATHEMATICS COMPREHENSION AND ATTITUDES TOWARDS MATHEMATICS AND COMPUTERS

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THE EFFECTS OF ANIMATED AGENTS WITH VERBAL AUDIO ON MATHEMATICS COMPREHENSION AND ATTITUDES TOWARDS MATHEMATICS AND COMPUTERS

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A candidate for the degree of Doctor of Philosophy of Information Science and Learning Technologies

And hereby certify that in their opinion it is worthy of acceptance.

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ABSTRACT

This doctoral study investigated the effect of animated agents with verbal audio in WBI on mathematics achievement and attitudes toward mathematics and computers using a pretest-posttest control group design model among eighty-one college students who enrolled in Pre-Calculus courses a at doctoral/research-extensive university. It verified quantitatively that the presence of animated agents with verbal audio in WBI can improve students' mathematics achievement and attitudes toward mathematics, but not their attitudes toward computers. In particularly, students in the experimental group practice effect improved, but not their application effect. In addition, this study verified that there exist a positive association between a student's attitude toward mathematics and his attitude towards computers and vice versa, and there exist a positive association between a student's satisfaction with WBI and her attitudes toward mathematics. Designers and developers of WBI can use these findings to better design, develop, and implement a web-based tutorial that promotes positive attitudes toward learning and long-term mathematics achievement in the postsecondary mathematics arena.

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CHAPTER I: INTRODUCTION

For the past fifteen years, many educational technologists, mathematics educators, and researchers have developed and evaluated web-based tutorials that assist students with learning mathematics. However, many of these tutorials do not include the presence of animated agents with verbal audio, forms of multimedia. The use of multimedia, such as, computers, audio, animation, animated agents, and video, in educational technology has grown exponentially (Koroghlanian & Klein, 2004; Najjar, 1996). These features can be included in computer-assisted instruction (CAI) and web-based instruction (WBI) and offer a 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).

The use of animated agents with verbal audio in educational technology has been found to enhance learning and motivate students to learn (Baylor, Ryu, & Shen, 2003; Craig, Gholson, & Driscoll, 2002; Moreno, 2001). However, because the use of animated agents with verbal audio in educational technology is still in its infancy stage, there exist little empirical research showing the notion that incorporating animated agents with verbal audio in instructional materials can improve student achievement and students' attitudes toward learning (Baylor, Ryu et al., 2003). Although there is some research that investigates the effect of animation (e.g., pictures, graphs, and diagrams) and audio on mathematics achievement and attitudes towards learning mathematics (Rehaag & Szabo, 1995), there is none that investigates the effect of animated agents with verbal audio on mathematics achievement and attitudes toward mathematics. In addition, because instructional materials that contain animated agents with verbal audio are mainly delivered via the computers, students' attitudes toward learning with computers must be assessed. Therefore, this study demonstrated that the incorporation of animated agents with verbal audio (speech) in a web-based learning environment can improve mathematics achievement and attitudes toward mathematics and computers.

Background

Computer-assisted instruction (CAI) is one of the many primary entities of educational technology (Cotton, 1991). Different forms of CAI, such as drill-and-practice activities, tutorials, games, and simulations, (Smith & Ragan, 1999) can be delivered via the computer using software or the Web.

Web-based instruction has been in existence since the 1990's (Schwier & Misanchuk, 1993). Technological advances, such as course management systems and Flash animation, have made WBI an attractive option for instructors. Furthermore, interest in using animated agents with verbal audio in web-based tutorials has increased recently, because "new technologies have made them more accessible" (Craig et al., 2002, p.428), and they have proven to be very effective in encouraging and motivating students to learn and change students' attitudes towards learning (André, Rist, & Müller, 1997; Barron, 2004; Bates, 1994; Blumberg & Galyean, 1995; Johnson, Rickel, & Lester, 2000; Lester, Stone, Converse, Kahler, & Barlow, 1997; Maes, Darrell, Blumberg, & Pentland, 1995; Stone & Lester, 1996; Tu & Terzopoulos, 1994).

Lester et al. (1997) examined the effects of an animated agent on problem-solving among one hundred middle students learning botanical anatomy and physiology. The animated agent assisted the students with designing a plant. Also, in 1997, André, Rist, and Müller developed and evaluated a web-based educational application that implemented an animated agent. In these early research studies, the presence and several characteristics of animated agents contributed to the improvement of student performance. One of the main characteristics of the animated agents that aided in this improvement was its speech (verbal audio).

Verbal audio technologies have been added to many instructional resources since the late nineteenth century with the invention of the phonoautograph in 1857 (Barron, 2004), which enabled instructors to communicate verbally with learners in remote locations, record lesson modules, and bring the voice of experts to the learning environment. In educational technology, audio on computers was primarily a monotonous feature (e.g., buzz or a beep) indicating inappropriate input (Barron, 2004). As the development of hardware and software improved, digital audio became vital in CBI (Barron & Kysilka, 1993). Audio in CBI flourished after the introduction of CD-ROMs. Thanks to streaming technologies, verbal audio is being utilized in WBI.

Streaming audio is used in WBI to *deliver the instruction that requires audio* via the Internet. Verbal audio created by a digitalized text-speech engine has been proven to enhance learning, motivate students to learn, draw and gain students attention, and reiterate lesson content that is printed on the screen (Aarntzen, 1993). When students are motivated to complete a task, they experience positive attitudes towards completing that particular task (Eagley & Chaiken, 1993).

Problem Statement

The majority of college majors that are not mathematically-intensive are requiring their students to complete mathematics courses in order to receive their degree, meaning that most postsecondary education students, regardless of their academic major, are now required to complete mathematics courses (Leatherman, 1994; Simmons & Jones, 2005). Most 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 their attitudes toward mathematics and previous learning experiences in mathematics education (Coben, O'Donoghue, & Fitzsimmons, 2000; Cohen, 2000; Jackson & Leffingwell, 1999). Thus, it is very important to design and develop learning environments in postsecondary mathematics education that can help improve achievement and attitudes among those students who are not mathematically oriented and express negative attitudes toward learning mathematics.

Although the effects of CAI and animation on mathematics achievement and attitudes toward mathematics and computers has been previously researched (Jennings & Onwuegbuzie, 2001; McCoy, 1996; Nooriafshar, 2002; Padberg & Schiller, 2002; Ramirez, 1990; Shashaani, 1995; Snelson, 2002; Szabo & Poohkay, 1996; Tooke, 2001; Wiest, 2001), there is a lack of research that investigates how the use of animated agents with verbal audio in a WBI environment can affect mathematics achievement and attitudes toward mathematics and computers in postsecondary mathematics education. In particular, there is little research regarding the use of these media with students who are not mathematically oriented and are apprehensive about enrolling in a mathematics course because of their attitudes toward mathematics and previous learning experiences in mathematics education. Previous research studies proved that animated agents with verbal audio can improve students' level of engagement, motivation, and achievement (Lester, Callaway, Stone, & Towne, 1997). However, these studies did not emphasize how animated agents with verbal audio can improve non-mathematically oriented college students' achievement and attitudes. Furthermore, the use of animated agents with verbal audio in WBI is a relatively new field in instructional technology and must be researched for effectiveness in postsecondary mathematics education.

By examining the effects of animated agents with verbal audio among college students who do not demonstrate the ability to excel in mathematics and are not intrinsically motivated to complete mathematical tasks, we can better understand the impact that animated agents with verbal audio have on learning and attitudes in postsecondary mathematics education. With this understanding, instructional designers and developers of any computerized learning tool that implements animated agents with verbal audio, can better design and develop an effective tool that is beneficial to diverse learners.

Purpose of the Study

The purpose of this study is to determine the effects of animated agents with verbal audio in WBI on learning in postsecondary mathematics education, by investigating learners' mathematics achievement, attitude change towards mathematics, and attitude change toward computers among college students. Several demographic factors – for example, gender, college classification, and WBI experiences – will also be examined to justify if these factors affect mathematics achievement and attitudes toward mathematics and computers. Investigating these factors is important when assessing learners' mathematics achievement (Frith, Jaftha, & Robert, 2004) and attitudes toward mathematics (Shashaani, 1995) and computers (Loyd & Gressard, 1984a). An investigation of certain learner characteristics can help instructional designers and developers of WBI, or any computerized learning tool, better design and develop an effective tool that is beneficial to learners from a diverse adult learning environment. Moreover, the differences of college classification and gender are significant factors that should be emphasized in research studies about adult learners in mathematics education, because these factors are "under-represented and under-researched" (Cohen, 2000).

Research Questions

The research questions for this study are as follows:

1. Does the presence of animated agents with verbal audio in WBI affect mathematics achievement, attitudes toward mathematics, and attitudes toward computers among college students based on gender, college classification, and WBI experience?
2. Is there a relationship between attitudes toward mathematics and mathematics achievement among college students?
3. Is there a relationship between attitudes toward mathematics and attitudes toward computers among college students?
4. Is there a relationship between student satisfaction with WBI and mathematics achievement among college students?

5. Is there a relationship between student satisfaction with WBI and attitudes toward mathematics among college students?

Theoretical Framework

Mayer's (2001) cognitive theory of multimedia learning provides an appropriate theoretical framework for studying the effects of animated agents with verbal audio on mathematics achievement and attitudes. It draws on assumptions from dual coding theory (Paivio, 1986), cognitive load theory (Mousavi, Low, & Sweller, 1995; Sweller, 1988), and constructivist learning theory (Baddeley, 1986). According to Mayer and his colleagues, cognitive theory of multimedia learning is a theory that explains how people learn and is based on the following assumptions: (1) The human brain includes independent visual and auditory working memory systems (Baddeley, 1986); (2) People use one "channel" in their brain to process visual information and another one to process auditory information (Paivio, 1986); and (3) There is a limit to how much information can be processed in each channel at a time (Mousavi et al., 1995; Sweller, 1988). Meaningful learning occurs when a learner selects relevant information from each storage memory, organizes the information into coherent representations, and makes connections between corresponding representations (Mayer & Moreno, 2003). Figure 1 demonstrates the Mayer's cognitive theory of multimedia learning.

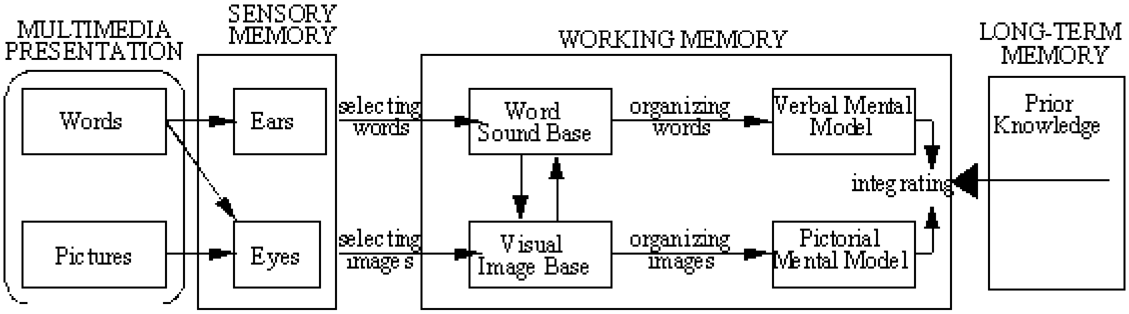

Figure 1. Mayer's cognitive theory of multimedia learning (Mayer, 2001).

In addition to the above assumptions, Mayer and his colleagues identified two principles that are significant to multimedia theory: modality and contingency. The modality principle is the belief that in a multimedia learning environment which involves verbal information and images, verbal information should be expressed orally through verbal audio. The contiguity principle consists of two effects: temporal-contiguity and spatial contiguity. The temporal-contiguity effect refers to learning improvements that are found when images and verbal audio are presented at the same time. The spatial contiguity effect refers to learning improvements that are "achieved when on-screen text and images are physically integrated" (Craig et al., 2002, p. 428). Mayer's theory has been applied to many cognitive phenomena, such as problem solving and concept learning, in many multimedia learning environments. In some respect, the combination of animated agents with verbal audio would seem to provide a challenge to multimedia environments, given the views of Mayer's theory.

Additionally, Mayer's theory can be used to assist students with learning mathematics in a multimedia learning environment. Mathematics is a subject matter that requires students to solve problems and understand concepts needed to solve those problems. The combination of an animated agent with verbal audio can help motivate students and improve mathematics achievement and student perception about learning by creating a virtual traditional face-to-face classroom setting (Johnson et al., 2000) and providing verbal explanations to well-defined problems. Furthermore, verbal and graphical interpretations of discrete and complex problems can help students verbally and visually understand the concept, whereas verbal or graphical interpretations only can make students more confused. Thus, the following statement represents the underlying logic for designing and conducting this study: The incorporation of animated agents with verbal audio in a mathematical learning environment can make learning easier and enjoyable and improve achievement and attitudes. If mathematical learning is enjoyable and easier, then the learner will express a positive attitude towards learning mathematics (National Council of Teachers of Mathematics, 2000).

Significance of Study

A study on the effects of animated agents with verbal audio implemented in WBI in postsecondary mathematics education is important for several reasons. First, understanding the effects of WBI in mathematics education, in general, is important for selecting and designing effective WBI tools. Educators should select instructional tools that are conducive to the learning environment and audience.

Second, understanding attitudes of college students (who are not mathematically inclined) toward mathematics could assist with attracting under-represented groups to the discipline. Because attitudes influence learning, instructional designers should design and develop tools that can positively change one's attitude about learning and "majoring" in mathematics (Coben et al., 2000).

Finally, understanding attitudes toward mathematics and computers, student satisfaction with WBI, and the effects of animated agents with verbal audio on mathematics achievement and attitudes toward mathematics and computers could assist with the instructional design of WBI mathematics courses. The design and development of WBI tools should relate to characteristics of the learner (e.g., attitude and satisfaction) and present characteristics (such as, animated agents with verbal audio) that will motivate students to engage in meaningful learning (Clarebout, Elen, Johnson, & Shaw, 2002; Koroghlanian & Klein, 2004).

Limitations, Delimitations and Assumptions

Limitations

The participants for this study represent a sample of convenience. Therefore, the results of this study may not be generalizable to the general population of non-math majors. Due to the lack of participation during the 2005 summer semester, recruitment of students enrolled during the 2005 fall semester was required. Only 17 students completed the study during the summer semester.

During the summer semester, it was common for students to stop participating after the second lesson module. It was believed that the lack of monetary compensation and the extra time to complete the modules were factors in the high attrition. Thus, only two lesson modules were used for this study, rather than implementing additional modules during the entire semester.

The value of the sample size $\left(\text{i.e., } N = 81\right)$ also decreases the generalizability of all the findings. The total number of students enrolled in the Pre-Calculus courses was 737. According to Barlett, Kotrlik, and Higgins (2001), the minimum returned sample size should have been 102 (with the margin of error = .03, alpha = .05, and t = 1.96).[1]

The pre- and post-lesson assessments contained identical problems, which might violate assessment validity. However, the problems on the exam were different from those on the lesson assessments.

Delimitations

This study was confined to the population of college students who (1) attended a doctoral/research-extensive university in central Alabama: (2) were undergraduates; and (3) were registered for a mathematics course in the summer and fall semesters of 2005.

This study was limited to investigating mathematics achievement using scores from pre- and post-lesson assessments, attitudes toward mathematics and computers, and student satisfaction with WBI based on the Mathematics Attitudes Inventory (Sandman, 1980), the Computer Attitude Scale (Loyd & Gressard, 1984b), and the Student Satisfaction [with WBI] Questionnaire (Stokes, 2003), respectively.

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[1] In most educational research studies that investigate achievement and attitudes, the alpha level that used to determine sample size is .05 and the t-value (for alpha level of .05) is 1.96. When analyzing continuous data, 3% margin of error is acceptable.

Assumptions

It was assumed that participants would honestly report demographic factors and their attitudes towards mathematics and computers and satisfaction with WBI and that the instruments will extract the desired responses.

It was also assumed that the responses from the instruments can be used to explain the participants' attitudes as they relate to mathematics and computers.

Finally, it was assumed that all participants followed instructions fully. For example, participants in the experimental group were instructed to keep the audio option "on".

Chapter Summary

This introductory chapter looks at the effects of animated agents with verbal audio in WBI in higher education. It suggests that the use of animated agents with verbal audio in WBI is increasing and very effective in improving students' achievement and motivation.

In addition, this chapter also looks at WBI in postsecondary mathematics education. The basics of multimedia learning theory and the knowledge, skills, experiences, and attitude that a learner brings to the learning environment were highlighted as important. Such information can help instructional designers and educational technologists better design and develop WBI environments to suit diverse communities.

Furthermore, this chapter provides the background information about the study. By discussing the purpose of the study, the research questions, and the theoretical framework, this chapter also shows that determining the effects of animated agents with verbal audio, implemented in a web-based mathematical tutorial, by investigating students' mathematics achievement and attitudes toward mathematics and computers and satisfaction with WBI, is the goal of this study. Limitations, delimitations, and assumptions that are associated with this study are also stated.

The remainder of this study is organized as follows. A literature review that relates to the investigation of the impact of educational technology, which includes the use of computers in a classroom setting, multimedia (animated agents and audio) and WBI, in higher education and attitudes toward mathematics, computers, and WBI is provided in Chapter Two. The methodology of the study, which includes the method of selecting a population, a description and the usage of the instruments, and the collection and the management of data, is provided in Chapter Three. Chapter Four explains the analysis and interpretation of the data collection. Finally, a discussion of the findings, conclusions, implications and recommendations is discussed in Chapter Five.

Definitions of Terms

For the purpose of this study, the following terms will be employed:

Achievement. A student's successful accomplishment, especially by means of exertion, skill, practice, or perseverance

Active learning. Based on the premises that students become more involved in the learning when they are engaged in creative work that is meaningful to them (Springer, 1997).

Adaptive learning. Refers to latent variables, such as motivation, self-efficacy, learning anxiety, language learning strategies, and oral performance, hypothesized to contribute to optimal performance (Woodrow, 2001).

Application Effect. Refers to student performance on in-class exam. The ability to demonstrate transfer of knowledge on an exam.

Asynchronicity. Assists in "…self-directed learning through flexible scheduling; both the learner and the instructor decide when and where to access course materials and other resources" (Hill, 1997, p. 76).

Attitude. The representation of an emotional reaction to an object, to the beliefs about an object, or to the behaviors toward the object (Galbrath & Haines, 1998)

Computer-Assisted Instruction (CAI). Refers to instruction that is being delivered via the computer (using software or the Internet) and acts as a supplement to traditional, teacher-oriented instruction (Cotton, 1991).

Computer-Based Instruction (CBI). "…refers to virtually any kind of computer use in educational settings, including drill and practice, tutorials, simulations, instructional management, supplementary exercises, programming, database development, writing using word processors, and other applications" (Cotton, 1991, p. 2).

Doctoral/Research Universities—Extensive. These institutions typically offer a wide range of baccalaureate programs, are committed to graduate studies through the doctorate, and award 50 or more doctoral degrees per year across at least 15 disciplines (The Carnegie Foundation for the Advancement of Teaching, 2004).

Mastery Learning. Mastery learning is based on Benjamin Bloom's Learning for Mastery model (Bloom, 1976) and proposes that any person can learn when provided with the appropriate learning conditions, which include an appropriate learning environment. (Bloom, 1976).

Multimedia. The combination of two or more of the following media: animation, audio, text, image, sound, speech, video, and computer programs which are digitally controlled by a computer (Acab, 1996).

Practice effect. Refers to how repetition in testing improves student performance.

Student performance. The assessment of students' achievement

Verbal redundancy. "…the simultaneous presentation of [on-screen] text and narration with identical words" (Moreno & Mayer, 2002, p. 156).

Web. A system of Internet servers that support specially formatted documents. The documents are formatted in a markup language called HTML (HyperText Markup Language) that supports links to other documents, as well as graphics, audio, and video files.[2]

Web-based Instruction (WBI). "…a hypermedia-based instructional program which utilizes the attributes and resources of the Web to create a meaningful learning environment where learning is fostered and supported" (Khan, 1997, p. 2).

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[2] http://www.webopedia.com/TERM/W/World_Wide_Web.html

CHAPTER II: REVIEW OF LITERATURE

In postsecondary education, computer technology, along with the Internet, the Web, and multimedia resources (such as animated agents with verbal audio), has made computer-assisted instruction (CAI) and web-based instruction (WBI) more effective (Barron & Kysilka, 1993; Johnson et al., 2000; Khan, 1997; Lester, Stone et al., 1997). Through the Web and with the integration of animated agents with verbal audio in WBI, students can download learning materials from the instructor, complete assignments with the help of animated agents that speak to them, and listen and watch lectures delivered by the instructor using a web cam. Furthermore, the use of animated agents with verbal audio has been implemented through the Web for solving large and complex computations that are otherwise unsolvable in the human mind. Thus, as long as animated agents with verbal audio are being used to deliver instruction via the Web, they will become important aids in a person's educational experiences. Hence, it is important to understand the learner's perceptions on learning from animated agents with verbal audio in a web-based learning environment.

The instructional tool used in this study is known as *Adam*. *Adam* is a multimedia web-based tutorial program that delivers mathematics lesson modules using animated agents with verbal audio. Because the primary technology used to deliver *Adam* is the computer, this literature review will present recent research studies on the impact of computers in education (in general) and mathematics education. It will also review literature that examines the impact of WBI and multimedia (e.g., animated agents with verbal audio) on achievement and attitudes. Finally, a review of literature on tutorials, a form of CAI and attitudinal research will be presented.

Computer Technology in Education

The introduction of technology in education is one of the most effective factors credited for the positive reform in the educational system (Berg & Bramble, 1983). Computer technology has assisted the educational system in both "the generation and dissemination of knowledge through research and instruction as well as in the variety of administrative functions and services" (Hallblade & Mathews, 1980, p. 29). Sidney Leavitt Pressey, B.F. Skinner, Norman Crowder, and Simon Ramo, early pioneers of computer-based instruction (CBI) and CAI, are responsible for the great innovation of computer technology and education (Niemiec & Walberg, 1989).

According to Niemiec and Walberg (1989), Sidney Pressey, who taught large introductory courses at Ohio State University in 1920s', developed machines to free himself and his graduate students from routine duties, such as administering quizzes to students. This invention eventually drew attention and reactions that would later start the development of the programmed instruction and the CBI movement (Niemiec & Walberg, 1989).

In 1954, B.F. Skinner developed the basis of behavioral analysis, suggested that a technology of behavior change was essential, and concluded that the program determined effectiveness, not the machine (Skinner, 1986). In addition, Simon Ramo (1957) visualized the two paths of development of CBI: computer-managed instruction (CMI), intended to manage students' records, and CAI, intended to deliver instruction to each student individually; whereas, Norman Crowder (1963) developed the branched programming, which is used in majority of today's CBI programs. From these historical innovations, the history of CBI offers some interesting hypotheses about the acceptance of technology in education.

In educational technology, computers have many uses. According to Handel and Herrington (2003), CAI applications can act as a *tutor* to guide individual learners; as a *tool*, students can use many applications, such as spreadsheets, graphing software, and databases, to complete tasks; and, as a *tutee*, students can program the computer to solve problems, such as in a LOGO environment.

Also, in educational technology, computers can be clarified as a cognitive tool or an instructional tool. Cognitive tools refer to technologies that can enhance an individual's cognitive process, whereas, instructional tools refer to technologies that aid instructors with their lessons. In some cases, computers can be used as both a tool and a tutor (Frith et al., 2004)[3].

Computers as Cognitive Tools

Jonassen and Reeves (1996) defined cognitive tools as certain technologies that strengthen the cognitive powers of an individual during the thinking, problem solving, and learning processes. They stated that cognitive tools (1) "actively engage learners in creating knowledge that reflects their achievement and conceptualization of information and ideas rather than absorbing predetermined presentations of objective knowledge" (p.

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[3] Using the computer as a tutor will be discussed later.

697); (2) are controlled by the learner, not the teacher; (3) require learners to think hard about the subject matter being studied or the task being completed and to produce thoughts that would be impossible without the aid of these tools; (4) are "unintelligent" tools, trusting that the learners will provide the intelligence; (5) enable learners to allocate to themselves "the responsibility for the cognitive processing" they do best, while they allocate to "the technology the processing that it does best" (p. 697). Furthermore, Jonassen, Carr, and Yueh (1998) quote:

> Computers can most effectively support meaningful learning and knowledge construction in higher education as cognitive amplification tools for reflecting on what students have learned and what they know. Rather than using the power of computer technologies to disseminate information, they should be used in all subject domains as tools for engaging learners in reflective, critical thinking about the ideas they are studying (p. 32).

In their study, Salomon, Perkins, and Globerson (1991) made an important distinction between *effects with technology* and *effects of technology* and concluded that they both explain why computers make people more intelligent. They also explained that effects *with* technology redefine and enhance performance as students work together with intelligent technologies that manage a significant part of the cognitive processing for the student, whereas, effects *of* technology takes place when the partnership between the student and technology "leaves a cognitive residue, equipping students with thinking skills and strategies that reorganize and enhance their performance even away from the technology in question" (p. 8). However, such benefits are not likely to occur automatically as technologies advance and improve. They should be appropriately enriched through the design of technologies and their cultural surroundings.

Computers as Instructional Tools

Since the early 1960s, instructional technologists have been developing program applications of CBI to drill and test students (Kulik & Kulik, 1991). According to Kulik and Kulik (1991), CBI program usage and the replacement of conventional teaching methods with CBI has increased in recent years. Many educational technologists believe that CBI will reduce educational costs and enhance educational effects, which add to the advantages of CBI.

In addition, Stern and Stern (1983) noted that computer availability, individualized instruction, student-machine interaction challenges, simulations, and instructional effectiveness are some of the advantage of CBI. Students will be able to learn at their own pace and implement their own learning styles efficiently with the help of effective CBI.

However, many disadvantages exist. Pedagogy and socialization are two of many disadvantages of CBI. In regards to socialization, the interaction between the teacher and the student may be reduced; meaning, the student may rely more on the computer for answers, help and motivation.

Even though, these disadvantages exist, CBI is still an effective instructional method in the educational curriculum. Kulik and Kulik (1991) conducted a meta-analysis to show that CBI produces positive educational effects. They concluded that not only does CBI have a positive effect on students, but it also produces positive attitudes towards teaching and computers among students and reduces the amount of time needed for instruction. Thus, teachers can cover more materials related to the subject matter during class time. Many educational researchers (Jonassen, Peck, & Wilson, 1999; Krendl & Lieberman, 1988; Kulik, Kulik, & Bangert-Drowns, 1985; Kulik, Kulik, & Cohen, 1980) agreed with these findings and suggested that positive effect can only occur if the computer is used effectively.

Computers are used to promote positive student learning in every subject. For example, students use them in Reading (Matthews, 1997), History (Tucker, 2002), English (Deal, 2003), and Second Language Learning (Liu & Reed, 1995) for better achievement. The subject where computer technology is greatly appreciated is mathematics. Computers can perform complex calculations and help students visualize complex graphs. Thus, computer assistance in mathematics education is an essential resource for mathematical learning.

Computers as Tutors

As a tutor, computers can guide students to learn at their own pace and reinforce lessons taught previously by the instructor. Tutorial programs, especially in mathematics education, can improve students' achievement and attitudes towards learning mathematics because they deliver students timeless instruction and explanations and immediate feedback (Frith et al., 2004; Morote & Pritchard, 2004; Reboli, 2003). A review of literature that investigates the impact of tutorial programs in mathematics education will be summarized later in this chapter.

Computer Technology in Mathematics Education

Various researchers, in particular, McCoy (1996) and Tooke (2001), found that CAI is effective in facilitating mathematics achievement. Tooke (2001) believed that computers enhance mathematics by allowing students to go beyond the imaginary and pencil-and-paper-only mathematics. The collaboration between mathematics and computers has an impact on many arenas in mathematics education, including mathematics teaching and mathematics learning.

Computers and Mathematics Teaching

Throughout the years, mathematics education has changed primarily because of computers. In order for computers to become effective tools for learning, teachers must be able to implement or incorporate them appropriately in their lessons (Wenglinsky, 1998). In order for this to happen, the personal and pedagogical philosophies of teachers must change (Thomas, Tyrrell, & Bullock, 1996). Thus, educators in mathematics teacher preparation need to instruct pre-service teachers in how, why and when to incorporate the computer in their lessons.

In addition, Wiest (2001) stated that "technology should be used as a medium that facilitates powerful mathematics learning rather than as an object of instruction" (p. 43). Therefore, the role of the teachers should be that of a facilitator of effective learning. Teachers should help students decide when and how to use the technology effectively. The National Council of Teachers of Mathematics (2000) concluded the following about the appropriate use of computers in mathematics education:

> The effective use of technology in the mathematics classroom depends on the teacher. Technology is not a panacea. As with any teaching tool, it can be used well or poorly. Teachers should use technology to enhance their students' learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently … (pp. 25-26).

Educational research has proven why it is important that computer technology and pedagogical philosophies should coincide (Connell, 1998). Cornell's findings suggest that a significant match can happen if (1) technology usage and the underlying instructional philosophy and approaches are in sync and (2) technology is used as a tool to allow students to create their own meaningful representation. He also believed that a student-centered, query-oriented learning environment that implements technology as a delivery system represents a "mis-cooperation" of instructional practices that can impact student learning negatively. Therefore, using technology appropriately means placing more emphasis on mathematical thinking in a learning environment with well-orchestrated instructional methods grounded in mathematics education theory.

Computers and Learning Mathematics

According to Courant, Robbins, and Stewart (1996), mathematics can be described, based on the foundation of the following basic elements - logic and intuition, analysis and construction, generality and individuality, as "an expression of the human mind" that reflects "the active will, the contemplative reason, and the desire for aesthetic perfection" (p. xxi). The concentration of mathematical knowledge is based on two basic concepts – computational and conceptual skills. Computational skills employ the use of rules, procedures, and algorithms, whereas conceptual skills mainly implement the use of strategies and problem solving. Both these skills require learners to produce results using rules and procedures. The difference between the two skills is how *explicitly* the problem informs the learners which operation to perform (Schunk, 2000).

Skemp (1987) concluded that students learn mathematics with relational understanding and/or instrumental understanding. Relational understanding refers to knowing what to do and why, whereas instructional understanding refers to rote-memorizing, or learning “rules [to solve problems] without reasons” (p. 153). From these understandings, Skemp goes on to define two types of mathematics – instrumental mathematics and relational mathematics. Even though, instrumental mathematics, which entails computational skills, is easier to understand, offers immediate and apparent rewards, and quicker results, relational mathematics, which entails mainly conceptual skills, allows learners to adapt to new tasks, remember concepts long-term, and fully understand the logic behind the solution to the task.

Computer-assisted instruction in mathematics education can assist with both forms of mathematics described above. Implementing tutorials that incorporate animated agents with verbal audio in mathematics education can enforce relationship mathematics by offering detailed explanations with text and speech in a virtual representation of a traditional learning environment and instructional mathematics by offering drill-and-practice problems and assessments.

Computer technology has many features that can impact student learning in mathematics (Wiest, 2001). Its multimedia applications can reinforce concepts and appeal to a variety of learning styles. Used as a tutorial, computer technology can help students who learn with relational and instrumental understanding. For example, graphical aspects can help students visualize and manipulate complex geometric figures and represent mathematical ideas such as the essence of arithmetic versus exponential growth (Wiest, 2001). The use of computer technology in mathematics education can help students grasp concepts better by manipulating complex concepts into easier, comprehensive ones.

According to Wiest (2001), computer technology is beneficial to students learning in mathematics, because "testing one's thinking and seeing the results" can be an influential way to maintain and broaden mathematical ideas (p. 45). Students can create instances from which they can try to simplify, "thus illustrating computing potential for pursuing the abstract and the general" (p. 45). However, Cuoco and Goldenberg (1996) stated that students could have too much computer confidence and move on too quickly without fully comprehending the subject. Thus, it is very important for teachers to understand their roles as facilitators.

Wiest (2001) also pointed out that CBI prompts individualized learning. Effective uses of good computer programs can allow students to work at their own pace and give them immediate, positive feedback on their performance. Numerous studies (e.g., Stern & Stern, 1983; Wiest, 2001) have found that personalizing word problems and individualized instruction have a positive effect on student interest and achievement.

Overall, computer technology has been an effective learning and teaching tool in mathematics education when used properly. Computer-assisted instruction (CAI) and WBI, primary entities of educational technology has aided in this success. Many research studies have shown that WBI has improved achievement and motivated students' perceptions about learning.

Web-Based Instruction

As stated in Chapter 1, the Web, along with multimedia resources, has become a form of communication that assist instructors in delivering instructional materials to students (Khan, 1997). WBI has proven to be an effective learning tool in many different educational arenas (Bailey, Hall, & Cifuentes, 2001; Felix, 2001; Hong, 2002; Jiang & Ting, 1999; Monteith & Smith, 2001; Padberg & Schiller, 2002; Powers & Mitchell, 1997; Shih & Gamon, 2001).

Shih and Gamon (2001) analyzed the relationship between student achievement and the following variables: attitude, motivation, learning styles, and selected demographics among 74 students enrolled in web-based courses in their study. Each participant completed a learning style test (Group Embedded Figures Test), an online motivation and attitude toward WBI questionnaire, and received a grade at the end of the courses. The learning style test classified participants as either field-dependent or field independent learners. Approximately 66% of the students taking the web-based courses were field-independent learners; however, there were no significant differences in achievement between field-dependent and field-independent learners. Furthermore, students with different learning styles and backgrounds learned equally well. Students enjoyed the convenience and self-controlled learning pace and were motivated by competition and high expectations in web-based learning. Motivation was the only factor that explained more than one-fourth of student achievement measured by course grades. Thus, the authors concluded that motivation influences learning.

In their study, Chou and Liu investigated (2005) on the effectiveness of a web-based virtual learning environment on basic information technology skills training among 210 junior high students. Results from a series of Analysis of Variances (ANOVAs) indicated that students learning in the web-based environment reported higher levels of achievement, computer self-efficacy and satisfaction with learning than the students in the traditional learning environment, concluding that WBI can be beneficial to students.

Furthermore, Yazon, Mayer-Smith, and Redfield (2002) explored how university students respond to and perform in a web-based learning environment, by examining whether technology can serve as a catalyst for reforming post-secondary education, and more specifically whether it can help educators address the problem of passive learning among college science students. To address these issues, 37 students' experiences in an ''auto-tutorial,'' web-based version of a third-year, university genetics course were evaluated. Results from this qualitative study indicated that a carefully designed technology-enhanced learning environment, which combines online and face-to-face elements has the potential to assist students in thinking differently about teaching and learning science. Thus, the authors concluded that the medium can change the message.

Ryan (2002) examined and evaluated a single course that was delivered in a traditional lecture-based section, as well as in a telecourse section and a Web-based section in his study, by comparing student achievement with regards to instructional delivery methods. The hypothesis of this study was that there was no significant difference between the three courses in terms of performance as measured by overall final course grade. Students enrolled in Math 155 (Introduction to Statistics) at Lakeland Community College (LCC) (Ohio) in 1999-2000 and who completed the pre-test and the final exam were studied. Among the 78 students, 41% of them were male and 59% female. Results from this quantitative study indicated no significant difference in student achievement, with regard to the instructional delivery method, as measured by overall final course grade. Thus, the author concluded that there was no harm to learners in institutions using alternative instructional delivery systems. Therefore, WBI in mathematic education may also be harmless.

WBI and Mathematics Education

WBI has been implemented in mathematics education for several years. However, only a few research studies investigated the impact of WBI on mathematics education (Bailey et al., 2001; Pilant, Hall, Epstein, Hester, & Strader, 2000; Usip & Bee, 1998). Before implementing WBI in mathematics, Pilant, Hall, Epstein, Hester, and Strader (2000) suggested several issues, such as, access and ease of use of technology, learning (assessment), and motivation, need to be addressed to guarantee that WBI will be effective.

In their study, Usip and Bee (1998) surveyed students enrolled in undergraduate economic statistics classes in an attempt to differentiate between users and non-users of WBI as a supplement to the traditional classroom lecture/problem-solving approach. Discriminant analysis and descriptive statistics tools were implemented to compare and contrast the perceptions of users and non-users. Results from this study indicated that users of WBI believe that distance learning via the Web was a good method of obtaining general information and a useful tool in improving their academic performance, whereas, non-users thought the university should provide financial assistance for WBI.

To investigate the impact of WBI on performance, Bailey, Hall, and Cifuentes (2001), furthermore, examined the impact of nine Web-based learning modules on learning as measured on both online module quizzes and in-class exams and determined that the learner characteristics and strategies affect student performance on the nine Web-based learning modules. Participants for this study included 147 students who were enrolled in two fall semester sections of freshman-level business mathematics courses and 191 students who were enrolled in two fall semester sections of freshmen-level Topics in Contemporary Mathematics courses. Data sources included: a demographic survey; nine Web-based instructional module quizzes; three in-class quizzes; three in-class, paper-based quiz surveys; an in-class final exam; an exit survey; and face-to-face interviews. Findings, from Multivariate Analysis of Variance (MANOVA), indicated that students who scored above 80% on the module quizzes also did better on in-class exams. Those who were self-motivated, focused, and self-disciplined had greater success in the online module environment than students who participated haphazardly or erratically in the modules. Hence, the authors concluded that Web-based modules support learning when used systematically by learners and that such modules extend the reach of the classroom teacher and reinforce classroom instruction. The use of multimedia in education can also add to this reinforcement.

Multimedia in Education

Multimedia resources, such as, animated agents with verbal audio, can assist with the delivery of instruction and communication among students and instructors, and improve achievement and student perception on learning (Johnson et al., 2000; Lester, Callaway et al., 1997; Mikk & Luik, 2003). This section examines the effects of animated agents and audio, in general, on student achievement and attitudes.

Animated Agents

Animated agents are implemented in CBI and appear on the computer 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). In previous studies, animated agents were proven to support cognitive functions such as problem solving, understanding, and learning and motivate students to learn (Dehn & van Mulken, 2000; Johnson et al., 2000). In addition, animated agents were only accepted by the learner if (1) the animated agent resembled the learner’s own personal characteristics and (2) the learner felt that he/she was in control (Baylor, 2003; Gilbert, Wilson, & Gupta, 2005; Lester, Converse et al., 1997; Norman, 1994).

There are two issues that the majority of animated agents researchers believe are critical roles in designing and creating engaging and believable animated agents: emotion (Bates, 1994; Delgado-Mata & Aylett, 2004; Gratch & Marsella, 2001; Lee, 1999) and deictic believability (Doyle, 2002; Lester, Converse et al., 1997; Lester & Stone, 1997; Towns, Callaway, Voerman, & Lester, 1998). Emotion refers to a person’s feelings and affection, whereas, deictic believability refers to how the coordination of behavior, gesture, locomotion, and speech in animated agents can make their presence believable.

In a quantitative study, Lester, Converse, Kahler, Barlow, Stone, and Bhogal (1997) examined the affective impact of animated agents on students' learning experiences among 100 middle school students (50 males and 50 females with an average of 12) who used Herman the Bug, a lifelike agent, in a virtual learning environment to learn problem-solving. Results from this study indicated that the *persona effect*, which is the presence of an animated agent in an interactive learning environment, can positively affect students' perceptions of learning. In addition, the effect of multiple types of behavior on affective perception and learning performance was also significant. Thus, the authors concluded that animated agents have profound effect on student perception and learning.

Furthermore, Prendinger and Ishizuka (2001) examined social role awareness as a desirable capability of animated agents. In particular, their goal was to investigate believability on the level of emotion expression rather than life-likeness. Results from this study indicated that an animated agent should represent "an overall consistency in its behavior in order to come across as believable to users and that social role awareness facilitates consistency" (Prendinger & Ishizuka, 2001, p. 276).

Rickenberg and Reeves (2000), however, tested the effects of different agent presentations on user anxiety and task performance among 84 students. Each student was assigned to one of the three groups: no-agent, ignorant-agent, or attentive-agent. The ignorant-agent ignored the user, whereas the attentive-agent monitored every work or task completed by the user. Results from this quantitative study showed that users felt more anxious and their performance decreased when their work was monitored by the agent. Thus, the author concluded that student performance will decline and anxiety level will increase if the student does not feel in control of their learning environment and agent.

Investigating animated agents' gestures, locomotion and speech was also considered important among researchers of animated agents to see if these characteristics affected learning. Towns, Callaway, Voerman, and Lester (1998) presented a framework for achieving deictic believability in animated agents. Using this framework, they created Cosmo, a web-based life-like agent. Among many users of the agent, Cosmo was found to be believable based on his behavior and utterance.

In her studies with many colleagues (Baylor, 2003; Baylor, Shen, & Huang, 2003; Baylor, 2002; Baylor, Ryu et al., 2003), Baylor thoroughly investigated how many distinct characteristics of the animated agents were involved in guaranteeing deictic believability. According to these studies, behavior, gestures, and speech proved to be predictors of deictic believability. To investigate the role of pedagogical agent gender and ethnicity, Baylor and Kim (2003) randomly assigned 139 students to one of four conditions that represented an agent's gender and ethnicity: AF (African-American Female), AM (African-American Male), CF (Caucasian Female), or CM (Caucasian Male). Results from ANOVAs indicated that male agents were perceived as more extroverted and agreeable than the female agents. Furthermore, students working with the male agents were more satisfied with their performance, and students working with agents of the same ethnicity perceived the agents to be significantly more engaging and affable. From these findings, the authors concluded that the students applied human stereotype to the agents.

Furthermore, Baylor, Shen, and Huang (2003) examined how students' gender and ethnicity influenced their choice of agents how and perception of persona of the chosen agents among 183 undergraduates from two southeast universities. Each student was allowed to choose from 8 agents who differed by gender (male, female), ethnicity (African American, Caucasian), and realism (realistic, cartoon). Results showed that African-American learners were significantly more likely to choose an agent with the same ethnicity and also to have positive attitudes toward the chosen agent after learning from it. In addition, female students were more likely to choose a cartoon-like agent and an agent based on their previous experiences with human instructors.

In conjunction with investigating the importance of emotion and deictic believability, many researchers examined the effect of animated agents on learning and student perception. Shaw, Lewis, and Ganeshan (1999) created an agent named Adele to be implemented in WBI and evaluated its effect on student perception and learning. Results from this quantitative study indicated that the system was easy to use and provided helpful hints and rationales. In addition, student learning increased among those who were able to use Adele for assistance.

In 2001, Moreno, Mayer, Spires, and Lester conducted a series of experiments to investigate if students can adapt to deeper learning when they interact with animated agents among middle and college students. In these studies, deeper learning was defined as "students' ability to use what they have learned to build a mental model of the scientific system and apply it to solve new problems" (Moreno, Mayer, Spires, & Lester, 2001, p. 187). In these five experiments, students learned how to design a plant using 8 different virtual learning environments. In the first experiment, 44 undergraduates participated. Each students was assigned to one of the two conditions: PA (the presence of the pedagogical agent) and No-PA (on-screen text only). Results from the first experiment indicated that students who learned with the agent did not differ in their retention of basic information from students who learned the same material from on-screen text. In addition, students in the PA group learned more deeply than the students in the No-PA group; meaning, the students in the PA group outperformed the students in the No-PA group. Finally, the results also showed that the students in the PA group significantly rated their interest in completing the task greater than the students in the No-PA group. Thus, the authors concluded from this study that animated agents can promote deeper learning and motivation to learn.

In their second experiment, Moreno, Mayer, Spires, and Lester (2001) set out to determine whether the pattern of results obtained in the first experiment with undergraduates will replicate in another study with younger learners. Thus, 48 seventh-graders (26 from an urban middle school were recruited for this study. Results indicated that, as in Experiment #1, students who learned with an agent did not differ significantly in their retention of basic information from students who learned with the absence of an agent; students in the PA group outperformed the students in the No-PA group; and, students in the PA group significantly rated their interest in completing the task greater than those in the No-PA group. The authors concluded that the findings of Experiments 1 and 2 provide solid evidence in favor of using animated agents in multimedia learning environment. Based on these findings, students are more motivated, more interested in learning, and achieve better when CBI lesson is presented in an agent-based environment rather than in an on-screen text environment.

Furthermore, in a third experiment, Moreno, Mayer, Spires, and Lester (2001) hypothesized that the main attribute promoting meaningful learning in an agent-based learning environment is the "students' active interaction and participation in the learning environment" (p. 197). For this study, students in the P group received explanations about material from the agent after they were given the opportunity to design the plant on their own, whereas, the students in the No-P group received explanations about material from the agent directly before being able to design the plant. Thirty-eight college students participated in this study. Results indicated that students in the P group recognition was significantly higher than the students in the No-P group; students in the P group achievement rate was not significantly differ from the achievement rate of students in the No-P group; and, the groups did not differ on interest in completing a task. The authors provided an explanation for the difference in the pattern of interest between Experiment #3 and Experiments #1 and #2 by saying

> ....the interactive attribute of a social agency environment is not sufficient to personalize the learning task and help students feel an emotional connection with the agent. The voice and image of the pedagogical agent may be the attributes needed to promote interest in the learning task (p. 199)".

Thus, a fourth experiment was initiated.

In Experiment #4, Moreno, Mayer, Spires, and Lester (2001) attempted to determine the role of the image of the agent, by comparing students' learning in CBI that included the image of an agent with an identical lesson in which the agents' image was absented, and the role of the voice by comparing students' learning in CBI that incorporated an agent that communicated via speech with an identical lesson in which the same words were printed on the screen. Sixty-four college students participated in this study. Each student was assigned to one of the four conditions: IT (image and text group), IN (image and narration group), No-IT (no image, but text group), and No-IN (no image, but narration group). Results from this quantitative study indicated that the visual presence of an agent did not affect students' learning or perceptions about the learning task. In addition, students remembered more information, achieve better, and were more interested in the learning task in a CBI lesson that communicates the lesson materials via speech rather than via printed text on the screen.

Finally, in Experiment #5, Moreno, Mayer, Spires, and Lester (2001) set out to test the hypothesis that a more expressive agent, in particular, a human agent, could promote deeper learning. This experiment is similar to Experiment #4 with the exception that the animated agent was replaced with a video of a real person. Seventy-nine college students participated in this study. Results from ANOVAs indicated that the incorporation of a human agent’s image in CBI did not detract learning, and students rated the computer program as being easier when speech is used rather than printed text. Thus, the authors concluded that the presence of animated agents and speech in CBI promotes deeper learning. Many research studies in educational technology supports this claim.

Craig, Gholson, and Driscoll (2002) explored the effects of redundancy on learning by investigating the effects of printed text, spoken narration, and spoken narration with the printed text in a multimedia educational environment that incorporated an animated agent. Seventy-one undergraduate students enrolled in an undergraduate psychology course volunteered to participate in this study. Each participant lacked the knowledge of the material presented by the agent and was equally distributed to one of the three condition groups: (1) spoken-text only; (2) printed-text only; and (3) spoken-plus-printed text. Results produced from a series of ANOVAs indicated that there was a significant difference among each group. Students in the spoken-text only significantly outperformed the students in the printed-text only group. Those in the spoken-plus-printed-text group had performed average and did not differ significantly from either of the other two groups. The authors concluded that these findings were surprising and limited by the briefness of information delivery and lack of knowledge.

Atkinson (2002) attempted to examine the effects of a problem solving computer-based learning environment that incorporates an animated agent using a dominant-less-dominant research design methodology in his study. The animated agent was coupled with a text-to-speech engine - computer software that is able to read typed-text aloud - to deliver the instructional explanations. Thirty undergraduate students participated in this pretest-posttest study design and were randomly and equally assigned to one of three condition groups: speech-plus-agent, speech-only, and text-only. The text-only group was the control group, and Analyses of Covariance (ANCOVAs) were used to analyses the three groups (alpha = 0.05) on learning outcomes. The score from the pretest was used as a covariate, and any significant differences not covered by an ANCOVA was re-examined with the Fisher's least significant difference (LSD) test. Contrary to Craig, Gholson, and Driscoll’s study, this study failed to establish any sort of effect of an animated agent on learning outcomes and the participants in the text-only group scores were statistically superior to those in the speech-only group. The author believed that three factors may have contributed to these unusual results: (1) low power due to the small sample size, (2) the design of the instruction, and (3) the speech which was generated by a text-to-speech engine.

However, Moreno (2001) previously tested the hypothesis that the use of animated agents in multimedia learning environments can promote deep learning by comparing learning and motivational outcomes of forty-four students who learned interactively with an animated pedagogical agent with those who learned in a conventional learning environment that implemented text and graphics. Results indicated that both groups learned basic factual information, however, the students who interacted with the agent produced significantly more correct solutions than the students who learned in the conventional environment. Thus, the author concluded that students who learn with animated pedagogical agents work harder to interpret the material and are more motivated and interested in learning than students who learn in a conventional text-and-graphics environment.

Baylor, Ryu, and Shen (2003) later investigated the effects of pedagogical agent voice and presence on learning among eighty undergraduate students enrolled in an educational technology course. Based on two-way ANOVAs, results indicated that learning was positively affected by the presence of the agent overall. However, there was a negative effect of agent presence on facilitative of learning. Based on these contradictory findings, the authors concluded that the agent presence might have increased the learners' cognitive effort towards learning, leading them to be "less satisfied". Finally, as for the effect of the agent's voice on learning, results indicated that having an agent's voice present promotes learning.

Finally, Merrill (2003) examined the effectiveness of animated agents on solving word problems skills. Results form this quantitative study indicated that students exposed to the animated agents outperformed those who were not. Thus, the author concluded that the including animated agents in CBI is beneficial to students who are learning how to solve word problems, an application in mathematics education.

Based on these studies and many other studies that investigate the role and importance of animated agents, the presence of animated agents in virtual learning environment is likely to become an integral part of future interfaces in educational technology (Rist, André, & Müller, 1997).

Audio

Audio is an essential instructional tool in multimedia instruction (Barron, 2004). The use of audio in multimedia instruction can draw and hold students’ attention and motivation and complement and support visual information (images) and printed text, which is displayed on the screen (Aarntzen, 1993). Because a computer is often a part of the multimedia learning environment that incorporates audio, audio will not usually be implemented alone (Aarntzen, 1993; Barron, 2004). There exist many forms of audio, e.g., sound effects, music, and speech. This study includes an investigation of the effect of verbal audio (speech) on mathematics achievement and attitudes. Therefore, research studies that examine the implementation and effect of speech in multimedia instruction are important.

In 1961, Samuel Postlethwait from Purdue University developed an audio-tutorial (A-T) approach to assist college students with learning biology. Based on results from an experiment conducted in 1962, Postlethwait reported that students using the A-T approach to learn did just as well as the students who learned in the traditional setting. Since then, many researchers (Barron & Kysilka, 1993; Brewer, 1970; Fisher & McWhinney, 1976; Flocker, 1972; Hahn, 1971; Kalyuga, Chandler, & Sweller, 1999; Kulik, Kulik, & Cohen, 1979; Montali & Lewandowski, 1996; Moreno & Mayer, 2002; Mousavi et al., 1995; Rehaag & Szabo, 1995; Sparks & Unbehaun, 1971) investigated the effect of A-T methods on student achievement and attitudes and concluded that A-T methods can improve student learning and attitude, but no significantly better than traditional teaching methods.

Worthington and Szabo (1995) compared the effects of interactive audio in CBI versus non-interactive audio in CBI on achievement and attitudes among 46 college music students. Each student was assigned to one of the two groups: experimental group (used interactive audio) and control group (used non-interactive audio). Results from this pretest-posttest control group design study indicated that the experimental group outperformed the control group, and there exist no difference in attitudes toward CBI between the two groups. Thus, the authors concluded that the use of interactive audio in CBI can perform student achievement.

Rehaag and Szabo (1995), furthermore, investigated the effect of including redundant digital audio in computer-based instruction (CBI) on mathematics achievement and time spent learning mathematics among eighty-two high school students enrolled in the Alberta (Canada) school system. Students were assigned to one of the following condition groups: CBI-audio-text or CBI-text. For the CBI-audio-text group, the lesson modules were modified by adding redundant audio that read the on-screen text instructions. Results from ANOVAs on mathematics achievement showed that there exist no significant differences in mathematics achievement between the two groups; however, results did indicate that redundant audio did reduce the time required to complete practice problems. Thus, the authors concluded that the latter does imply that redundant audio in CBI can improve learning efficiency.

In their study, Montali & Lewandowski (1996) attempted to demonstrate how the efficacy of an audio-visual approach affect reading achievement among eighteen middle school students who were average readers and eighteen middle students who were low-skilled readers. Students were introduced to and asked to read social science passages in a computerized learning environment. To assess reading achievement, students were then asked to answer ten open-ended questions. The material was presented in three ways: visual-only, audio-only, and audiovisual. Results from this quantitative study indicated that overall reading achievement was significantly greater when the learning material was presented visually and orally. In addition, less skilled readers comprehended more with the visual-auditory presentations than the other two, and their word recognition increased. The authors concluded that visual-auditory presentation of learning material can increase achievement, and learners who need extra assistance with learning can benefit more from visual-auditory presentations of instructional materials.

In addition, Kalyuga, Chandler, and Sweller (2000) examined the effects of dual-mode (visual and auditory presentation of text along with a graphic) instruction on learning among sixty trade apprentices from two major Australian manufacturing companies in their study. Each participant was randomly assigned to one of the following four condition groups: (1) a graphic with visual text, (2) a graphic with auditory text, (3) a graphic with visual and auditory text, or (4) the graphic only. Results from a series of ANOVAs indicated that auditory and visual presentation of text along with graphics proved superior to the auditory-only and visual-only presentations of text. However, when the graphic-only group was compared to audio-text only after additional training, the graphic group outperformed them. The authors accredited this finding to the learners' experiences and knowledge of the program and material.

Finally, Moreno & Mayer (2002) examined the effects of non-redundant and redundant explanations along with animation in a multimedia learning environment among seventy-four undergraduate students enrolled in a psychology course. The primary issues that the authors wanted to address were concerns whether students can learn content more deeply when the explanations are presented both orally and visually.

Results from this quantitative study indicated that the students remembered significantly more knowledge about the material and generated significantly more creative solutions when verbal explanations were redundant with the printed text on-screen. Thus, the authors concluded that adding verbal redundancy to on-screen text in a computerized learning environment can help students' retention of knowledge.

As for investigating students attitudes toward using audio in instruction, Rehaag and Szabo (1995) examined the effect of including redundant digital audio in CBI on attitudes toward CBI among eighty-two high school students enrolled in the Alberta (Canada) school system. Students were assigned to one of the following condition groups: CBI-audio-text or CBI-text. For the CBI-audio-text group, the lesson modules were modified by adding redundant audio that read the on-screen text instructions. Results showed no significant differences in attitudes toward CBI between the two groups. However, the lower ability students expressed more positive attitudes toward CBI than did the high ability students.

Furthermore, Barron & Kysilka (1993) investigated the effectiveness of audio on student perceptions toward CAI among 60 college students. Each student belonged to one of the three condition groups: text-only delivery, full-text and totally redundant audio delivery, or partial-text with full audio delivery. Results from this study indicated that student perception was high across all levels of treatments. Thus, the authors concluded that the use of audio in CAI is not detrimental to learning. Moreover, the use of audio in WBI tutorial programs is accepted among many educational technologists if it is implemented properly.

Drill-and-Practice and Tutorial Programs in Mathematics Education

There are many practices or forms of CAI, such as drill-and-practice and tutorials (Wang & Sleeman, 1996). Tutorial programs are educational applications of computer technology that takes of advantage of the computer timeless patience and abilities to provide immediate feedback and reinforcement. They are one-step ahead of drill-and-practice programs, because they can offer detailed instruction that deliver explanations of a lesson as well as practice problems to improve and assess learning and can reinforce concepts or skills that have been learned or taught previously by the instructor (Burns & Bozeman, 1981; Din, 1996; Valdez et al., 2000). Because this study investigates the effects of certain characteristics of a CAI tutorial that implements drill-and-practice in a web-based community, this section will summarize recent research studies that investigated CAI tutorial and drill and practice programs in mathematics education. In addition, the majority of these studies evaluated CAI tutorial and drill and practice programs among K-12 students, but not among postsecondary students. It is also important to examine this type of instructional method in the postsecondary arena, because it is being implemented in different disciplines, such as statistics, physics, and mathematics.

Drill-and-Practice

Harrison and Van Devender (1992) examined quantitatively the effects of drill-and-practice CAI on learning basic arithmetic among ninety-three fourth-grade students. The participants were divided into one control group which received traditional classroom drill-and-practice instruction only and two experimental groups which received CAI in addition to the traditional classroom instruction. Using ANOVA, results indicated that a significant difference in subtraction and multiplication achievement. The students learning along with CAI drill-and-practice program outperformed the students who were not using the CAI program. The authors concluded that the use of drill-and-practice CAI program in mathematics education can improve mathematics achievement.

In his study, DeVaney (1996) examined the effects of CAI and calculators on computation and mathematics achievement among nine hundred fifty-six eighth graders in Mississippi. He also examined possible relationships between achievement differences related to demographic and background characteristics. Results indicated significant differences in computation and achievement between African-American and Caucasian students and between males and females. Furthermore, the results showed significant negative associations between the frequent use of computers and using computers for drill and practice.

Jackson, Kutnick, and Kington (2001), furthermore, investigated student performance among eighty-seven elementary students using a CAI drill and practice program to complete tasks. Each student either completed the tasks individually, in pairs, or using paper-ad-pencil, not the computer. Results from this quantitative study indicated that students working individually were more likely to complete the tasks using a CAI drill and practice successfully than students working in pairs.

Finally, Wong (2001) investigated the effects of three methods of computer-assisted homework assignments and paper-based homework assignments on achievement, retention, attitudes, and homework time among one hundred eighty-seven secondary students. The three methods of CAI used in this study were drill-and-practice, games, and computer-aided discovery. The CAI drill-and-practice group consisted of forty six students; the CAI game group consisted of forty-six students; the computer-aided discovery group consisted of forty-eight students, and the paper-based homework group consisted of forty-seven students. Results from this study quantitatively indicated that the CAI drill-and-practice group outperformed in the least amount of time than the other three groups, proving that CAI drill-and-practice assignments are most beneficial. The author accredited this success to the availability of online help and immediate feedback.

Tutorial Programs

Morote and Pritchard (2004) examined the correlation of twelve background variables, which included previous level of knowledge in algebra, physics, calculus, trigonometry and geometry, technological experiences, age, gender, grade level, and academic major among one hundred seventy-five students who completed paper-based testing assessments (final exam and weekly tests) and web-based assessments generated by a web-based homework tutorial. Results indicated that the level of previous physics and mathematics courses taken correlated with positive results on paper-based testing assessments, whereas, access to computer correlated with positive results on the final exam only. However, none of the background variables correlated with the web-based tutorial homework scores. Thus, the authors concluded that timeless use of web-based tutorials can make "important contribution to assessing student performance, without bias due to students' background differences" (p. 826).

Frith, Jaftha, and Prince (2004) later examined learning with interactive spreadsheet-based computer tutorials in a mathematical literacy course among sixty-seven students by investigating the effects of completing a computer tutorial before or after lecture sessions in their study. Results from this quantitative study indicated differences between learning experiences in the lecture sessions and the computer laboratories. The computer tutorials were more effective in conveying the concepts than the lecture sessions. This finding was based on the analysis of the difference scores between pre- and post-assessments. From this finding, the authors suggested that CAI tutorials, along, with lecture sessions in mathematics education, can improve mathematics achievement.

As stated in the previous studies, CAI online tutorial and drill-and-practice programs can encourage and motivate students to learn, which has a positive effect on their attitudes toward learning. Thus, if these programs are implemented in mathematics education, most likely students might express positive attitudes toward learning mathematics and learning with computers through WBI.

Attitudinal Research

According to Wlodkowski (1999), attitude is one of many motivational conditions that influences an adult motivation to learn. In general, an *attitude* is a composite of concepts and emotions that results in a willingness to respond favorably or unfavorably toward certain people, ideas, situations or objects (Wlodkowski, 1999). The affection of attitudes on human behavior and learning is powerful because attitudes “help people make sense of their world and give cues as to what behavior will be most helpful in dealing with that world" (Wlodkowski, 1999, p. 72). Attitudes make people feel safe among the unknown and help them entertain and deal with recurrent events.

Although attitudes can by influenced by many social factors, they are still learned. Because attitudes are learned, they can be changed or modified. Attitudes are with us always and will constantly influence our behavior and learning (Wlodkowski, 1999) New educational experiences constantly influence our attitudes toward learning and vice versa, which can make both of them better or worse. When instruction begins, students (particularly, adult students) will tend to make judgments immediately about the teacher, the subject, the learning task, and their success expectancy (Wlodkowski, 1999)..

Attitude Change

One of the most common types of communication is a discussion aimed at changing people's attitudes, which is known as persuasion. Its success depends on several factors (Gale Group, 2001). The first factor is the source, or communicator, of a message. To be successful, a communicator must have credibility based on his or her alleged knowledge of the topic and be considered trustworthy. "The more the perceived similarity between communicator and audience is, the greater the communicator's effectiveness" (Gale Group, 2001).

The second factor is intelligence. The effect of intelligence on attitude change is inconclusive. However, it has been hypothesized that the greater one's intelligence, the more willing one is to consider changing their points of view. On the other hand, people with superior intelligence may be less easily persuaded because they are more likely to detect weaknesses in another person's opinion.

Finally, the medium of persuasion also influences attitude change. The medium is the message. Face-to-face communication is usually more effective than mass communication. The effects of persuasion may take different forms. Sometimes they are evident right away; at other times they may be delayed known as "sleeper effect" (Gale Group, 2001). In addition, people may often change their attitudes only to change over time to their original opinions, especially if their environment supports the initial opinion (Eagley & Chaiken, 1993). It has been proven that students, particularly in mathematics education, tend to reflect the same attitude as their teacher (Aiken, 1972).

Attitudes toward Learning

Students bring into the learning environment attitudes that may affect their ability and motivation to learn (Wlodkowski, 1999; Zahn, 1969). Based on previous research studies, Zahn (1969) investigated three types of adult attitudes that affect learning – powerlessness, conflicting needs, and role transition. She concluded that students who have strong feelings of powerlessness might be incapable of learning the lesson that is being taught by the teacher. Thus, it is important for educators to recognize the learners' current role position in the relation to their motivation to learn, the steps in the role change process and how each step may affect the learning process. Zahn finally stated that if the learning task explanation opposes any personal needs or habits, learning would be more difficult. Therefore, students will be more motivated to listen to and read content which represent a personal experience that may occur or increase their capability to complete a learning task (Manteuffel, 1982; Zahn, 1969).

Educators can also improve student learning by promoting intrinsic motivation. Intrinsic motivation exists when the source of motivation lies within the individual and task (Ormrod, 1999). Students find the learning task enjoyable or worthwhile completely. If students experience intrinsic motivation while learning, they will most likely experience success with their learning (Ormrod, 1999).

Attitudes toward Computers

Because computers are one of the main required tools to complete WBI, the investigation of students' attitudes toward computers is appropriate. Research on attitudes toward computers is heavily studied in the field of primary and secondary education (Clements, 1981; Lawton & Gerschner, 1982; Shashaani, 1994). Many researchers investigated factors such as, gender, computer experience, age, computer usage, parents' stereotypes, and personality (Loyd & Gressard, 1984a; Shashaani, 1994).

Sacks, Bellisimo, and Mergendoller (1993-94) examined the relationship between students' attitudes toward computers and computer use over a four-month period among gender. They concluded that girls' attitudes toward computers improved while the boys' attitudes did not. However, there was no evidence showing overall gender differences in computer use, nor an increase in computer use. The authors also revealed that girls' attitudes toward computers and computer use were related, while the boys' attitudes toward computers and computer use were unrelated. However, boys' attitudes toward computers were stable, while the girls' attitudes toward computers were unstable.

Shashaani (1997) examined the gender gap in computer attitudes and use based on a sample of 202 college students (115 females and 87 male) majoring in various fields such as computer science, mathematics, pharmacy, communication, sociology, and political science. She surveyed student attitudes in relation to gender, experience, and parental encouragement and determined that females were less interested in computers and less confident than males and males were more experienced. Further analysis of students' responses showed that one semester of computer training improved their attitudes toward computers. As for parental encouragement, students reported that their parents, especially fathers, tended to agree that men know more about computers, have more ability to use them, and believed that the study of computer is more appropriate for males. Knowing this information, young women who perceived their parents' attitudes in this way had less interest and confidence in using computers, hence, influencing their attitudes toward computers. Furthermore, male students agreed that their parents encouraged them to take computer courses and to learn more about computer, whereas, female students disagreed that they had received such encouragement. Drawing from her findings, the author suggested that training and use have a positive effect on women's' attitudes toward computers, and parents' positive attitudes and encouragement appear to be important in motivating females to become involved with computers.

In addition, Schumacher, Morahan-Martin, and Olinsky (1993) conducted a study that investigated computer experience and attitudes as well as computer and mathematics anxiety and their effect on grades in a computer-based course among (31 male and 30 female) college graduate students. Based on results from a questionnaire that assessed computer experiences and attitudes toward computers and mathematics and factor analysis testing, attitudes toward computers were positive, overall, but some of the students were anxious about using computers. Furthermore, female students were more experienced with the use of data entry and accounting computing applications and were more likely to regard computer knowledge as career enhancing than were male students. Finally, computer experiences were significantly related to computer attitudes and anxiety and mathematics anxiety was the only significant predictor of course grades. Mathematics anxiety was associated with lower mathematics course grades in both computer-based and non-computer-based courses. Thus, according the authors, it is important to deliver knowledge in a context that is appealing to the learner.

Czaja and Sharit (1998) examined age difference in attitudes toward computers as a function of computer experiences and computer task characteristics among 384 adults ranging from the ages 20 to 75 years in their study. Each participant had to perform one of the three real-world tasks (data entry, database inquiry, and accounts balancing) for a three-day period. A computer attitude scale was used to assess attitudes toward computers before and after the task. Results indicated that there were no age differences in overall attitudes. However, there were age effects on several attitude dimensions - comfort, efficacy, dehumanization, and control. In general, older adults (60-75 years) perceived less comfort, efficacy, and control over computers than did younger (20-39 years) and middle-aged (40-59 years) adults. Results from this quantitative study also indicated that computer experiences resulted in more positive attitudes for all participants across most attitude dimensions. These effects were moderated by task and gender. Thus, as concluded by the authors, computer attitudes are modifiable for people of all age groups, and the nature of computer experience has an impact on attitude change.

Dyck and Smither (1994), in addition, compared older adults (55 years and over) to younger adults (30 years and under) on levels of computer attitudes and anxiety and computer experiences. Participants completed a demographic and computer experience questionnaire, the Computer Anxiety Scale, and the Computer Attitude Scale. Results from this correlational design study indicated that older adults were lesser computer anxious, had more positive attitudes toward computers, had more liking for computers, but had less computer confidence than younger adults. Furthermore, for both adult groups, higher levels of computer experience were associated with lower levels of computer anxiety and a more positive attitude toward computers. No gender differences were found for computer anxiety or computer attitudes when computer experience was controlled.

In their study, Chisholm, Irwin, and Carey (1998) examined computer training preferences, computer attitudes and perceptions, and computer access among Chinese, Ghanaian, and American students in college business and education classes using results from a four-part questionnaire. Results indicated that the differences in computer ownership among students reflected economic realities. The majority of the American students have computers at home; the few Chinese and Ghanaian students who own a computer were likely to be children of university professors and to live at home. Furthermore, the willingness of Chinese and Ghanaian students to share a computer had economic and cultural roots; 42.3% of the Chinese and 31.3% of the Ghanaian students preferred to share the computer while working in the university labs. Only 7.1% of the American students preferred to share a computer. The use of DOS versus Windows--the majority of the Chinese students used DOS without Windows--indicated that the power and relative state-of-the-art of Chinese computers is significantly lower than in the United States. In terms of attitudinal differences, the Chinese and Ghanaians felt as positive towards computers as American students, though they have less access to computers. Thus, the authors concluded that access and competency are closely linked, and that while the attitudes of Chinese and Ghanaian students are positive towards computers, they have little experience and competence in using them.

Lau and Ang (1998) further reported on results of a quantitative study that investigated attitudes toward computing among 509 students undertaking an introductory information systems course in an Australian university. Students were surveyed using a two-part questionnaire. The first section dealt with questions pertaining to gender, previous computing experience, level of computer knowledge, age, program of study, year of study, and mode of study (i.e., full-time or part-time). The second section consisted of 24 questions related to attitudes toward computing. Results, generated from Chi-square data analysis, indicated that age and gender did not have a significant influence on attitudes toward computing. However, previous computing background and level of computer knowledge did significantly influence attitudes toward computing. Suggested by the authors, based on their findings and many other studies, the relationship between the traditional gender stereotype and attitudes toward computing no longer exist, and increased computer experience alone can reduce computer anxiety, thus ensuring positive attitudes toward computing.

Finally, Walters and Necessary (1996) surveyed 204 college students (103 underclassmen and 101 seniors) at a large mid-western university to measure computer attitude differences using the 24-item Attitude Toward Computer Scale developed by Francis (1993). Based on analysis of variance test results, a number of statistically significant differences were found between underclassmen and graduating seniors for student demographics such as the number of university computer courses previously taken, years of computer experiences, computer ownership, and overall knowledge of the computer. Other variables such as gender, number of high school computer science courses, and grade point average were found non -significant. Thus, the authors concluded that gender and achievement, two of the main factors that can be used to predict attitudes toward computers in past studies, were no longer valid.

Results from these research studies vary, but the majority agrees that students have positive attitudes toward computers. From these research studies, one can also conclude that people could learn and would like to learn with computers.

Attitudes toward WBI

The effect of WBI on student attitudes has been investigated in previous studies. Gilbert, Wilson and Gupta (2005), for instance, investigated the effect of *Adam*[4], a web-based instructional system that incorporates animated agents on students' attitudes toward learning in computer science education among 302 college students (244 males and 58 females) enrolled in an introductory computer programming course. Results from this

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[4] The tool used in this study.

study indicated that the students' attitudes toward learning and motivation to learn positively increased. Thus, the authors concluded that animated agents can encourage and motivate learning.

In his study, Hong (2002) investigated the effect of students' and instructional variables on satisfaction and achievement in a constructivist web-based statistics course among 26 college students by gathering data from the students through questionnaires, faculty's record, and interviews. Based on Kendall's Tau-c data analysis, results from this mixed methodology study indicated that gender, age, learning styles, time spent on the course, and perceptions of student-student interactions, course activities, and asynchronous web-based communications (through discussion boards) were not related to satisfaction and learning outcomes. In addition, those students who entered the course with better cumulative grade point average (CGPA) achieved higher final grades in the course but did not express more satisfaction with the learning environment. Computer experience did not influence achievement; however, experienced computer users were more satisfied with the course (don't understand this part of the sentence). Students, who perceived the student-instructor interactions positively, felt that their discussion group had performed well, viewed the learning materials used from the discussion boards positively improved their grades and were more satisfied with the course. Students from this study expected instructor-led learning. Thus, the authors concluded that there is a need to explicitly design an organized strategy to assist students in completing the problem-based learning processes during web-based instruction and discussion.

Stokes (2003) surveyed undergraduate college students enrolled in courses that incorporated Web-based modules to assess their satisfaction with learning in a digital instructional environment with the goal of identifying possible predictors of satisfaction according to temperament, preferred learning styles, and the demographic characteristics of gender, age, grade point average, major according to academic division, experience with using the WWW, and previous courses taken that incorporated Web-based lessons. In this study, temperament classifications were guardian, artisan, idealist, and rational, and were determined through the Keirsey Temperament Sorter II. Preferred learning style categories were active/reflective, sensory/intuitive, visual/verbal, and sequential/global, based on Felder and Solomon's Index of Learning Styles. Satisfaction was measured on a 16-item satisfaction scale developed by the researcher. Results indicated that the level of experience with using the WWW and gender were significant predictors of student satisfaction when all other variables were controlled. Students who described themselves as being at ease with using the Web were more likely to be satisfied with the digital learning environment. Females were more likely to be satisfied with digital learning than were males. The author, in conclusion, stressed the importance of reassuring students who are considering enrolling in courses that incorporate digital learning, but who may be reluctant to register because of perceived mismatches between personal traits and the digital environment, that the environment is not restrictive in terms of temperament, preferred learning styles, age, grade point average, university classification, major, or previous digital learning experience.

Felix (2001) finally reported on a large scale study carried out in four settings that investigates the potential of WBI for learning English as a second language, both to complement face to face teaching and as a stand alone course among 63 college students. Data were collected by questionnaires and observational procedures to ascertain student perceptions of WBI. Results indicated that students were on the whole positively inclined to working with the web and found it useful, with the majority preferring to use WBI as an addition to face to face instruction. Even though the students felt that WBI enabled time flexibility, reinforced learning, privacy and wealth of information, they also felt that the disadvantages of WBI were distraction, absence of teacher and personal interaction and lack of speaking practice.

Attitudes toward Mathematics

The investigation of students' attitudes toward mathematics is essential to this research study because they can determine future enrollment in higher-level mathematics classes and career interests in science and mathematics (Aiken, 1972; Matthews, 1984; Rech, 1994). Thus, the improvement of negative attitudes is vital.

Countless factors influence attitudes that many students have toward mathematics. Aiken (1963) concluded that attitudes toward mathematics were highly related to their perceptions of their previous mathematics teachers and that there was a significant relationship between students' attitudes and mathematics as a male domain. Female students felt that mathematics was too complex and made for males to comprehend.

Furthermore, Aiken concluded that personality has an effect on students' attitudes toward mathematics. He stated that attitudes toward mathematics were significantly related to leadership potential among males and to adjustment to reality among females. In addition, students who have positive attitudes toward mathematics tend to be more sociable and intelligent, more self-controlled, and place more value on theoretical matters than those who have negative attitudes toward mathematics.

Aiken (1972) investigated students' attitudes toward mathematics and its relationship between mathematics achievement and parents' and teachers' attitudes toward mathematics. He suggested that students' attitude towards mathematics are important in determining whether they will enroll in higher-level mathematics courses, participate in mathematics activities, and preserve those efforts once they began.

Aiken also added that parents and teachers' attitudes toward mathematics influence children's' attitudes toward mathematics. Since children first experience mathematics with parents, their attitudes will reflect those of their parents. Moreover, because mothers spend more time with children than fathers, attitudes of both sons and daughters toward mathematics are closely related to the mothers' attitudes toward mathematics than those of the fathers (Aiken, 1972). However, fathers' expectations of success in mathematics influence their sons' expectations.

Finally, Aiken (1972) stated that teachers, as well as peers, may influence attitudes toward mathematics. Teachers' attitudes toward mathematics and effectiveness in mathematics are viewed as prime determinants of students' attitudes and performance in the subject (Aiken, 1972). Aiken's study and other research studies (Ruffel, Mason, & Allen, 1998) support this assertion by concluding that the teachers' understanding, effectiveness, and appreciation of mathematics are significantly related to their students' attitudes. Thus, teachers who exhibit positive attitudes toward mathematics can result in more positive attitudes toward mathematics among their students.

Signer (1996) studied the interaction among ethnicity, socioeconomic status (SES), mathematics achievement level, and gender on student beliefs about themselves as learners of mathematics through in-depth interviews with high school students. One hundred high school students were interviewed. Half were: (1) African American or White; (2) female or male; (3) high-math or low-math achievers; and (4) residing in high and low SES communities. Dependent variables, based on student responses, were educational aspirations and mathematics self-concept, while demographic variables such as gender and ethnicity were independent variables. Results revealed interactions of mathematics achievement by ethnicity, ethnicity by math achievement by SES, and gender by math achievement. The significant reported interactions involve mathematics achievement, yet mathematics coursework and achievement levels are not commonly studied when reporting socioeconomic, gender, and ethnic differences of mathematics attitudes. Males were more likely than females to attribute intrinsic constructs as reasons for their mathematics grades. The author concluded that findings about African American students support research that dispels the myth that African American youth have little academic self-concept and are not easily discouraged by low achievement.

Attitudes toward Computers and Mathematics: The Relationship

Computers have been associated with mathematics education for quite some time. According to several researchers, (Gressard & Loyd, 1987; Shashaani, 1995; Tooke, 2001), mathematics is the foundation of computer science. Calculators and computing mathematical applications are used for problem solving and achievement of mathematical knowledge (Borba, 1995). As long as computers are being implemented in mathematics instruction, the investigation of the relationship between students' attitudes toward computers and mathematics education is essential.

Jennings and Onwuegbuzie (2001) examined whether the variables of age, gender, attitudes toward mathematics, and student type are significantly related to four dimensions of computer attitude: anxiety, confidence, liking, and usefulness among 351 male and female students who were divided into three age groups and equally divided between developmental and non-developmental status in mathematics education. Data were collected via a survey instrument that combined demographics with the Loyd and Gressard (1984a) Computer Attitude Scale and the Fennema-Sherman (1976) Mathematics Attitude Scale. Results from a multiple analysis of variance revealed no main effect for gender with respect to dimensions of computer attitude. A main effect, however, was found for age, indicating that the youngest group of students reported less computer anxiety and higher levels of confidence than did the other age groups. The oldest students reported the highest levels of computer liking and perceived usefulness of computers. Also, students with the highest level of math attitudes had the highest score for all four dimensions of computer attitude. Finally, relative to non-developmental students, developmental students reported significantly more positive attitudes toward the dimensions of computer attitude except perceived usefulness. Thus, the authors concluded that developmental students were likely to be exposed to instruction with computer enhancement in their developmental programs, and computer use in developmental programs can be beneficial in their educational pursuits.

In their study, Galbraith and Haines (1998) investigated the impact of technology on mathematics achievement among 156 students using six Galbraith-Haines scales. Results from this quantitative study indicated that computer influence determines students' attitudes toward computer-mathematics interaction. Thus, the authors concluded that students do take into consideration attitudes and motivation when providing responses to situations that employ mathematics and computing.

In addition, Shashaani (1995) described a study that examined gender differences in mathematics experience and attitudes as well as the association between math attitudes and computer attitudes. Results from this quantitative study indicated that math liking was related to computer interest and computer confidence but was unrelated to computer stereotype. Furthermore, students who were more confident about their ability to perform mathematical tasks were more interested in using computers and had more confidence working with computers. In general, these findings suggested that "having more mathematical skills lead to more positive attitudes toward mathematics, which in turn positively affects computer attitudes" (p. 36).

Chapter Summary

Computer technology is a part of our daily lives and is implemented in many businesses, schools, and homes to help people survive in this society. In addition, computer technology has been incorporated in many instructional modules to encourage and improve education. For example, in mathematics education, computer technology can be used to solve problems, but when misused, create problems. Therefore, people must learn how, why and when to use it efficiently.

The impact of CAI, WBI, and multimedia in the educational system has been beneficial. Students are more motivated to learn and comprehend the subject matter quickly and better. Because computer technology is used as an educational resource in our schools, it is important to understand students' attitudes toward computers. With this understanding, educators can better prepare instruction that will accommodate every student.

Mathematics education is one form of education that implements CAI. With the help of computer technology and animated agents with verbal audio, mathematics achievement scores have increased, and more and more students are starting to realize why mathematics is so important.

This literature review examined why technology is so essential to mathematics education for all learners and the attitudes of students toward computers, WBI, and mathematics. It has been predicted and suggested that WBI in mathematics education can create positive attitudes toward mathematics; thus, improving students' motivation to learn mathematics. However, it has not been proven or shown that the integration of animated agents with verbal audio in a web-based learning environment can enhance learning and student motivation in postsecondary mathematics education.

CHAPTER III: METHODOLOGY

This chapter described the methods used for this study. The research purpose was to determine the effects of animated agents with verbal audio in web-based instruction (WBI) on learning in postsecondary mathematics education, by investigating mathematics achievement, attitudes toward mathematics and computers, and student satisfaction with WBI among college students. Several demographic factors – for example, gender, college classification, and WBI experience – were examined to justify if these factors affect mathematics achievement and attitudes toward mathematics and computers. Investigating these factors is important when assessing learners' attitudes toward mathematics (Shashaani, 1995) and computers (Loyd & Gressard, 1984a). An investigation of certain learner characteristics can help instructional designers and developers of *Adam*, or any computerized learning tool, better design and develop an effective tool that is beneficial to learners from a diverse adult learning environment.

Research Questions

The research questions for this study were as followed:

1. Does the presence of animated agents with verbal audio in WBI affect mathematics achievement, attitudes toward mathematics, and attitudes toward computers among college students based on gender, college classification, and WBI experience?
2. Is there a relationship between attitudes toward mathematics and mathematics achievement among college students?

3. Is there a relationship between attitudes toward mathematics and attitudes toward computers among college students?
4. Is there a relationship between student satisfaction with WBI and mathematics achievement among college students?
5. Is there a relationship between student satisfaction with WBI and attitudes toward mathematics among college students?

Description of the Population

The sample for this study was 81 adult learners (23 males and 58 females) who were college undergraduate students attending a doctoral/research-extensive university in central Alabama during the summer and fall semesters of 2005. 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. As for race/ethnicity, 88.9% of the participants were Caucasian, 6.2% were African-American, 2.5% were Hispanic, and the other 2.4% belonged to other ethnic groups.

The ages of the participants ranged from 19 to 24 years. Approximately 71% of the participants were 19 years of age, 9.9% were 20 years of age, 9.9% were 21 years of age, and the other 19.1% were 22 years of age or older. In the state of Alabama, a person is considered an adult at the age of 19.

Each participant was enrolled in a Pre-Calculus course that was offered by the Department of Mathematics and Statistics. Five sections of the Pre-Calculus course participated in this study and were taught by different instructors, including the author of this document. The sample represented non-STEM (Science, Technology, Engineering, and Mathematics) majors and was chosen based on convenience. Approximately 44.1% were Business majors, 25.8% were Literal Arts majors, 14.8% were nursing majors, 11.1% were Education majors, 2.5% were counseling majors, and the rest (1.7%) were undecided.

Instruments

The instruments that were used for this study were (1) the Computer Attitude Scale (CAS) (see Appendix B), which was developed by Loyd and Gressard (1984b) and contained the demographic survey used in this study, (2) the Mathematics Attitudes Inventory (MAI) (see Appendix C), developed by Richard Sandman (Sandman, 1980), (3) the Student Satisfaction [with WBI] Questionnaire (Stokes, 2003), developed by Suzanne Stokes (see Appendix D), and (4) lesson modules and assessments, developed by the author of this document (see Appendix E).

The Computer Attitude Scale

The Computer Attitude Scale (CAS) (Loyd & Gressard, 1984b) is a 40-item four-point Likert type scale, which provides a total score on the measure of attitudes toward computers and subscales scores on computer anxiety, computer confidence, computer liking, and computer usefulness. Each statement should have been read carefully and answered with one of the following responses: Strongly Agree, Slightly Agree, Slightly Disagree, or Strongly Disagree. The scale required approximately twenty minutes to complete.

Validity and Reliability of CAS

The Computer Attitude Scale (Loyd & Gressard, 1984b) has a proven record of reliability and validity. Reliability refers to internal consistency and temporal stability of scores and the implementations of form equivalence (American Psychological Association, National Council on Measurement in Education, & American Educational Research Association, 1985), whereas validity refers to the meaningfulness, representation, and quality of inferences made about scores (Messick, 1995).

Gardner, Discenza, and Dukes (1993) highly recommended the CAS for research studies assessing attitudes toward computers. Woodrow (1991), furthermore, concluded that the overall reliability coefficients of the subscales of CAS were high, indicating that each subscale is consistent and stable enough to be used separately and "the total score gave a reliable measure of attitudes toward computers and their use" (p. 181).

The CAS also has a proven record of consistency. Loyd & Loyd (1985) administered the scale to 114 teachers enrolled in microcomputer staff development courses. The study examined the reliability, the factorial validity and the differential validity of the CAS and its subscales. Results indicated that the CAS was reliable in measuring adult learners' attitudes toward computers and differentiating attitudes among adult learners with different amounts of computer experience. The coefficient alpha reliabilities for the computer anxiety, computer confidence, computer liking, and computer usefulness subscales were .90, .89, .89, and .82, respectively. An estimation of .95 for the total score was realized. Because the reliability coefficients were high, the

CAS is a reliable and valid instrument to use to measure attitudes toward computers among adult learners.

Massoud (1990) conducted a similar study using 59 low-literate adults in reading, writing, and mathematics as participants. The population sample was adults in GED classes who were learning inclusively between the fifth and twelfth grade levels. The coefficient alpha reliabilities ranged from .79 to .91 for the CAS and its subscales. As for validity, Massoud's study produced factor loadings greater than or equal to .40, which are considered significant. Thus, because the reliabilities were high and the factor analysis results were significant, the CAS is a reliable and valid measure of computer attitudes among adults and could be confidently used.

Many other research studies (Gardner et al., 1993; Gressard & Loyd, 1987; Loyd & Gressard, 1984b; Massoud, 1990; Roszkowski, Devlin, Snelbecker, Aiken, & Jacobsohn, 1988; Woodrow, 1991) also examined the reliability and validity of the CAS and concluded that it is a reliable and valid instrument for measuring attitudes toward computers.

Mathematics Attitudes Inventory

The Mathematics Attitudes Inventory (MAI) was developed by Richard Sandman (Sandman, 1980). The MAI is a 48-item four-point Likert scale that is composed of six subscales: perception of mathematics teacher, mathematics anxiety, value of mathematics in society, self-concept in mathematics, enjoyment of mathematics, and motivation in mathematics. Each statement should have been read carefully and answered with one of the following responses: Strongly Agree, Agree, Disagree, or Strongly Disagree. The inventory took approximately twenty minutes to complete. This instrument was developed as a part of National Science Foundation (NSF) project (Sandman, 1980).

Validity and Reliability of MAI

In a study concluded by Sandman (1980), the reliability and validity of the MAI were examined. The MAI was administered to two large samples of secondary mathematics students. A total of 5034 students were measured. The coefficient alpha reliabilities ranged from .68 to .89 for all six subscales. A factor analysis of the subscale scores generated six factors. These factors were associated with the six concepts that the instrument was designed to measure. Thus, the MAI is a reliable and valid measure of attitudes toward mathematics.

Student Satisfaction [with WBI] Questionnaire

The Student Satisfaction Questionnaire (SSQ), developed by Suzanne Stokes, is a 16-item 3-point Likert scale that assesses students' satisfaction with WBI. Questions on the SSQ were based on perceptions attained from research literature (Biner, Dean, & Mellinger, 1994; Wernet, Olligies, & Delicath, 2000) and input from a team of instructional technology experts employed at the University of Alabama (Stokes, 2003). Each item should have been read carefully and answered with one of the following responses: Often, Sometimes, Seldom, or, "I do not know". The questionnaire took approximately ten to fifteen minutes to complete.

Reliability and Validity of the Student Satisfaction Questionnaire

The SSQ was studied by a team of instructional experts and established face validity. The reliability coefficient for the scale was 0.83 using Cronbach's alpha method

(Stokes, 2003) Thus, the SSQ is reliable and acceptable tool to assess students' satisfaction with WBI.

Lesson Module Assessments

Two lesson module assessments separately tested students' knowledge about (1) solving quadratic functions and (2) graphing piecewise functions. Each lesson assessment contained three problems that only tested knowledge about one lesson module. To view the lesson assessments, see Appendix E.

Materials

Adam

The computerized tool that was implemented in this study is known as *Adam*. *Adam* is a WBI system that accommodates learners by offering various forms of instruction created by multiple instructors using animated agents with verbal audio. These characteristics of *Adam* improved students' level of engagement with the lesson modules (Gilbert, 2002).

Animated agents are implemented in computer-based instruction (CBI) and appear on the computer 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 animated agents, which are embedded in *Adam*, exhibit speech and eye and head movements. They are mainly used to deliver verbal representations of the instruction to gain the learner's attention. In previous studies, animated agents were proven to support cognitive functions such as problem solving, understanding, and learning (Dehn & van Mulken, 2000; Johnson et al., 2000).

Audio is usually added to CBI to gain attention and increase motivation with voiced materials, sound effects, musical interludes, and congratulatory phrases (Koroghlanian & Klein, 2004). According to Koroghlanian & Klein, audio research studies investigating the efficacy of audio combined with animation instruction are mixed and suggest that the effect of audio combined with animation may be related to the characteristics of the animation (the agents), the type of learning measured, and the characteristics of the learner.

Finally, *Adam* uses a random instruction method selection algorithm to select an instructional unit. The completion of each instructional unit is marked by an assessment quiz. If the learner performs 80% or better on the assessment quiz, then the learner has completed the lesson module successfully. However, if the learner performs less than 80%, the same lesson will be taught using a different instruction method, meaning that the same content will be explained in a different way. For a detailed description on *Adam*, refer to Appendix A.

Lesson Modules

For this study, participants in the experimental group were asked to complete the following lesson modules using *Adam,* a WBI system that delivers mathematics lesson modules using animated agents with verbal audio, whereas the participants in the control group were asked to complete a paper version of the same lesson modules without using *Adam*.

The lesson modules used in this study were chosen based on degree of difficulty. Most non-STEM majors completing a Pre-Calculus course experience a high level of anxiety toward mathematics when learning these lessons. For a full description of the two lesson modules, refer to Appendix E.

Lesson Module #1: Solving Quadratic Equations.

A **quadratic equation** is an equation of the form

$$ax^2 + bx + c = 0,$$

where a, b, and c are real numbers, with $a \neq 0$.

This lesson module demonstrates how to solve quadratic equations:

- by using the square root property, when $b = 0$,
- by factoring using the zero factor property,
- by completing the square, and
- by using the quadratic formula.

Lesson Module #2: Graphing Piecewise-Defined Functions.

This lesson module demonstrates how to graph piecewise-defined functions. If f is a function, the values of the function can be expressed in a list or table of values. This expression assigns to every x in the domain of f exactly one y in the range of f, where $y = f(x)$. The set of all points in the plane is called the **graph of *f***. Another way to state the definition: the graph of a function f is the set

$$\{(x, f(x)) \mid x \in \text{domain of } f\}.$$

In a **piecewise-defined function**, the domain of the function is divided into several sections and a different function applies to each section. For example, the following function

$$f(x)=\begin{cases} x^2 & \text{if } x>0 \\ x+1 & \text{if } x\le 0 \end{cases}$$

is a piecewise-defined function. The function $f(x)=x^2$ applies only when x falls in the interval $(0,\infty)$, and the function $f(x)=x+1$ applies only when x falls in the interval $(-\infty,0]$.

Data Collection and Analysis Procedures

Data Collection Procedure

This study implemented a pretest-posttest control group design with matching. Participants were divided into two groups: an experimental group and a control group. There were thirty-eight participants in the experimental group and forty-one participants in the control group. Based on Borg & Gall's (1989) procedure for a pretest-posttest control group design with matching, participants were assigned to matched pairs on the basis of their pre-assessment scores received from the first lesson module. For example, two participants who received a 4 on the pre-lesson assessment were paired together; two participants who received a 3 on the pre-lesson assessment were paired together, and so on. Then, one member of each pair was randomly assigned to the experimental group and the other member to the control group[5].

The experimental group completed lesson modules using *Adam*, whereas the control group completed paper versions of the lesson modules without using *Adam*. The control group did not have access to the animated agents with verbal audio and immediate feedback from the practice assessments. However, both groups had access to the same curriculum, materials, syllabus, exams, and a face-to-face learning environment, which will be taught by different instructors, including the author of this document.

During both semesters, a two-week data collection process was implemented. This process was divided into three stages: pre-assessment stage, lesson module completion stage, and post-assessment stage. Prior to the pre-assessment stage, participants in an experimental group received a step-by-step web-based tutorial to help them use *Adam*. The tutorial displayed detailed procedures for logging-in and getting started with *Adam*. If students had any questions regarding the use of *Adam* or experience any technical difficulties, they consulted the Help section available through *Adam* or the author of this document.

The purpose of the pre-assessment stage was to gather data that reflect participants' attitudes toward mathematics and computers *before* the introduction of *Adam*. During the pre-assessment stage, each participant was asked to perform the following tasks:

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[5] Due to discontinued participation of some students, the number of participants between the two groups is uneven.

1. Complete the Loyd-Gressard's Computer Attitude Scale.
2. Complete the Sandman's Mathematics Attitude Inventory.

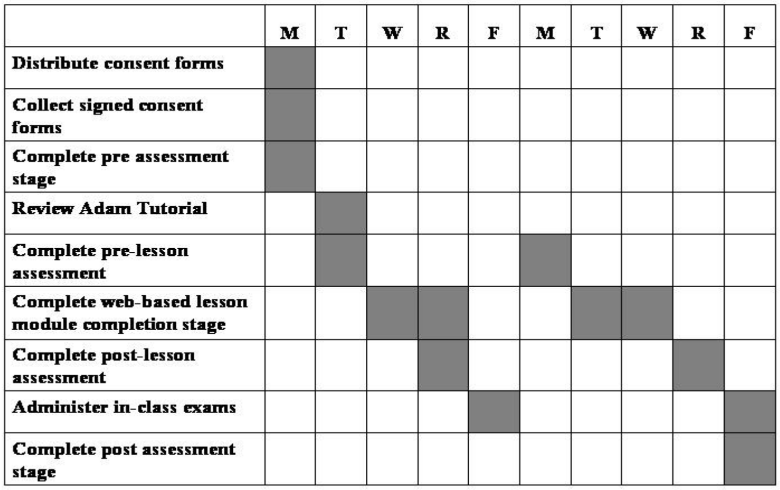
After completing the pre-assessment stage, the participants began the lesson module completion stage. Before the introduction of each lesson module, each participant was asked to complete a pre-lesson assessment that corresponded with the proceeding lesson module. Then, each participant in the experimental group was asked to complete the lesson module using *Adam* in a computer lab on campus, and each participant in the control group was asked to complete the paper-based version of the lesson module. The control group participants received feedback from the assessment quiz that was included in their lesson module packets at the end of this stage. 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 and the author of this document questions pertaining to the lessons and *Adam* while completing this stage.

Finally, data were gathered during the post-assessment stage that pertained to participants' attitudes toward mathematics and computers and satisfaction with WBI *after* completing all of the lesson modules. Participants were asked to perform the following tasks in this stage:

1. Complete the Loyd-Gressard's Computer Attitude Scale.
2. Complete the Sandman's Mathematics Attitude Inventory.
3. Complete the Stokes' Student Satisfaction [with web-based instruction] Questionnaire.

Participants in the experimental group were the only subjects that completed item #3 in the post-assessment stage. The comparison of quantitative data collected from these stages would help to indicate if *Adam* can or did improve mathematics achievement and attitudes toward mathematics and computers.

Data collection occurred outside the classroom setting. Each participant in the experimental group completed all stages of the data collection process in a computer lab on campus. Data was only collected on the weekdays (Monday-Friday). Figure 2 provides a detailed timeline for the data collection process.



	M	**T**	**W**	**R**	**F**	**M**	**T**	**W**	**R**	**F**
Distribute consent forms	■									
Collect signed consent forms	■									
Complete pre assessment stage	■									
Review Adam Tutorial		■								
Complete pre-lesson assessment		■				■				
Complete web-based lesson module completion stage			■	■			■	■		
Complete post-lesson assessment				■					■	
Administer in-class exams					■					■
Complete post assessment stage										■

Figure 2. Data Collection Process Timeline.

Independent Variables

The independent variables for this study were: WBI using *Adam* and several demographic factors – college classification, gender, and WBI experience-, which were retrieved from the CAS instrument. To measure WBI experience, each participant was asked if they ever enrolled in a course that utilizes WBI and/or completed a WBI course. Table 1 illustrates the transformation of the demographic factors.

Table 1. *Transformation of Demographic Factors*

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

Adam was implemented outside of the traditional learning environment. The experimental group used *Adam* to complete the lesson modules described above. It was accessible on any computer that had an Internet connection, which used Digital Subscriber Line (DSL) technology, a cable modem, a T1 connection, or better, a Haptek Player plug-in[6], and an Internet browser. For best results, Microsoft Internet Explorer version 6[7] or later and Netscape version 7[8] or later were recommended Internet browsers.

Dependent Variables

The dependent measures for this study were: the difference of mathematics achievement post- and pre-lesson assessment scores, the difference of attitudes toward mathematics post- and pre-assessment scores, and the difference of attitudes toward computers post- and pre-assessment scores. Furthermore, student performances on exam problems that were related to the content delivered via *Adam* were compared between the

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[6] http://www.haptek.com

[7] http://www.microsoft.com/windows/ie

[8] http://www.netscape.com

two groups. The lesson assessment scores measured practice effect, whereas, the average score of the exam problems measured application effect.[9] Refer to Appendix F to view exam problems.

Data Analysis Procedures

Instruments were checked for completeness, and the author of this document ensured that all participants were 19 years or older and non-STEM majors. The performance of the experimental and control group was compared by employing one-way and two-way analysis of variance (ANOVA) on differences scores. The difference score for each participant and group was calculated as follows:

Difference Score = Post-assessment score – Pre-assessment score

Table 2 illustrates the data collection and analysis procedures that was used for this study.

Table 2. *Data Collection and Analysis Procedures*

<table>
<tr><td colspan="3">Research Question #1. Do WBI with animated agents with verbal audio affect mathematics achievement, attitudes toward mathematics, and attitudes toward computers among college students based on gender, college classification, and WBI experience?</td></tr>
<tr><th>Data Collection</th><th>Variables</th><th>Data Analysis</th></tr>
<tr><td>CAS, MAI and lesson pre- and post-assessments scores
Exam scores</td><td>Dependent: Difference scores between post- and pre-lesson assessments
Difference scores between post- and pre-assessment of attitudes toward mathematics and computer
(Difference scores were calculated by subtracting the pre-assessment scores from the post-assessment scores.)</td><td>One-way and two-way ANOVAs on difference scores were conducted for each dependent variable.
Two-way MANOVAs on difference scores were also conducted.</td></tr>
</table>

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[9] Transfer of knowledge refers to being able to use the explanations delivered in the lesson modules to solve new problems.

	Independent: *Adam*, college classification, gender, and WBI experiences	
Research Question #2. Is there a relationship between attitudes toward mathematics and mathematics achievement among college students?		
Data Collection	**Variables**	**Data Analysis**
MAI and the lesson post-assessment scores	Case 2.1: Post-mathematics achievement scores-predictor variable; post-attitude towards mathematics scores-criterion variable Case 2.2 Post-attitude towards mathematics scores-predictor variable; post-mathematics achievement scores-criterion variable	Perform correlation analyses on Cases 2.1 and 2.2.
Research Question #3. Is there a relationship between attitudes toward mathematics and attitudes toward computers among college students?		
Data Collection	**Variables**	**Data Analysis**
MAI and CAS post- assessment scores	Case 3.1: Post-attitude towards computers scores-predictor variable; post-attitude towards mathematics scores-criterion variable Case 3.2 Post-attitude towards mathematics scores-predictor variable; post-attitude towards computers scores-criterion variable	Perform correlation analyses on Cases 3.1 and 3.2.
Research Question #4. Is there a relationship between student satisfaction with WBI and mathematics achievement among college students?		
Data Collection	**Variables**	**Data Analysis**
SSQ and lesson post-assessment scores among the experimental group	Case 4.1: Student satisfaction with WBI scores-predictor variable; post-mathematics achievement scores-criterion variable Case 4.2 Post-mathematics achievement scores-predictor variable; student satisfaction with WBI scores-criterion variable	Perform correlation analyses on Cases 4.1 and 4.2.
Research Question #5. Is there a relationship between student satisfaction with WBI and attitudes toward mathematics among college students?		
Data Collection	**Variables**	**Data Analysis**
SSQ and MAI post-assessment scores among experimental group	Case 5.1: Student satisfaction with WBI scores-predictor variable; post-attitudes toward mathematics scores-criterion variable Case 5.2 Post-attitudes toward mathematics scores-	Perform correlation analyses on Cases 5.1 and 5.2.

	predictor variable; student satisfaction with WBI scores-criterion variable	

Similar studies (Liu & Reed, 1995; Loyd & Gressard, 1984a; Sacks et al., 1993-94) used analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) for data analysis to investigate the effect of an independent variable on dependent variable(s) and simple regression analysis to investigate the relationship of two variables. For this study, each data analysis was executed using a statistical package for social sciences (SPSS) version 12.0.

Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) is a series of statistical tests that are based on the partitioning of variability in the dependent variable. According to Myers and Well (1995), components of variability associated with the main effects of the factors and the joint effects of combinations of factors are obtained and compared with the component that reflects error variability. For example, for a design with a single independent variable, the variability in the dependent variable would be partitioned into two components: one associated with within-group score differences (this provides an estimate of the error variability), and a second component associated with between-group differences that might be in part due to error variability and in part due to the effects (if any) of the independent variable. The decision about whether the independent variable has statistically *significant* effects is based on whether the between-group differences are large compared with what might reasonably be expected if the independent variable had no effect so that between-group differences would be due only to error variability. To test for homogeneity of variances, the Welch's test of equality of means was executed because the cell sizes for the independent variables, gender, college classification, and WBI experiences, were unequal (Myers & Well, 1995).

Multivariate Analysis of Variance (MANOVA)

Multivariate Analysis of Variance (MANOVA) is the multivariate extension of ANOVA (Tabachnick & Fidell, 2001). The difference between the two is that MANOVA is preferred when a situation has several dependent variables. According to Tabachnick and Fidell (2001), MANOVA evaluates “differences among centroids [vectors] for a set of dependent variables when there are two or more levels of an independent variable (groups)” (p. 21). The results of MANOVA also provide the impact of main effects as well as interaction effects. When analyzing multiple dependent variables using MANOVA, with a small sample, Pillai's trace multivariate test is the preferred statistic (Walker, 1998).

According to Garson (2005), “the Pillai’s trace is the sum of explained variances on the discriminant variates, which are the variables which are computed based on the canonical coefficients for a given root”. Multiple discriminant analysis is a component of MANOVA, where canonical roots are computed. Olson (1976) concluded that the Pillai’s trace was the most robust among the four multivariate tests and is, thus, sometimes preferred.

To answer research question one, one-way and two-way ANOVAs were conducted on the difference scores for each dependent variable to determine if animated agents with verbal audio in WBI had a positive or negative effect on students’ mathematics achievement, attitudes toward mathematics and computers, and satisfaction with WBI. Additionally, two-way MANOVAs on difference scores for multiple dependent variables were also conducted. Statistics from the Pillai's trace multivariate test were reported.

Correlation Analysis

Creswell (2002) described a correlation as a statistical test to determine the tendency or pattern for two (or more) variables or two sets of data to vary consistently. In other words, this test describes and measures the degree of association (or relationship) between two or more variables or sets of scores. Furthermore, in a correlational research design, variables are not manipulated or controlled by the analyst or researcher.

To answer research questions two, three, four, and five, a prediction research design was conducted. A **prediction research design** is a type of correlational design that identifies variables that will positively predict an outcome or criterion (Creswell, 2002). A **predictor variable** is the variable used to make a conjecture about an outcome. The variable used to represent the outcome being predicted is called a **criterion variable**. In the case of predicting students' attitudes toward WBI in mathematics (criterion variable), the predictor variable might be the observation of students who are learning from WBI systems in mathematics classes, or just their "mathematics achievement scores".

Level of Significance

The level of significance is the probability that the statistic will be in the critical region (values of the statistics that are agreed to cause rejection of the hypothesis) when the hypothesis is true(Dixon & Massey, 1983). Because a probability level of .05 has been generally used for data analysis in research studies examining students' attitudes, this study will use a level of significance to answer the research questions.

Chapter Summary

The effects of animated agents with verbal audio in postsecondary mathematics education were determined by investigating the pre- and post-assessment scores that reflect students' mathematics achievement, attitudes towards mathematics and computers, and satisfaction with WBI. College students who were non-STEM majors and enrolled in Pre-Calculus courses during the summer and fall semesters of 2005 were the participants in this study. Scores achieved by participants on pre- and post-lesson assessments assessed mathematics achievement. Attitude measurements on mathematics and computers were assessed by the Mathematics Attitudes Inventory (MAI) and the Computer Attitude Scale (CAS), respectively. Student satisfaction with WBI was measured using the Student Satisfaction [with WBI] Questionnaire (SSQ). The MAI, CAS, and SSQ were proven to be reliable and valid instruments for assessing attitudes toward mathematics and computer and student satisfaction with WBI. Data collection occurred at the beginning and the completion of the each lesson module. ANOVA and MANOVA were used to compare difference scores between pre- and post-treatment scores and the average of exam problem scores, whereas, a simple correlational regression analysis was used to indicate if certain factors are associated with others. Data were analyzed using a statistical package for social sciences (SPSS). Permission was granted from the Institutional Review Board on the University of Missouri-Columbia and Auburn University campuses and Dr. Michel Smith, Chairman of the Department of

Mathematics and Statistics at Auburn University to conduct the study on Auburn University campus.

CHAPTER IV: RESULTS

The presentation and interpretation of results from this study as they relate to the research questions posed are outlined in this chapter. The purpose of this study was to determine the effects of animated agents with verbal audio, which are embedded in a WBI system known as *Adam*, on learning in adult-based mathematics education, by investigating learners' mathematics achievement, attitude towards mathematics, attitude towards computers, and satisfaction with WBI among college students. Particular attention was focused on reportable differences or statistically significant relationships between gender, college classification, or WBI experiences, and mathematics achievement, attitude change toward mathematics, or attitude change toward computers among students who used *Adam* to complete lesson modules compared to those who did not.

Prior to analyses, all variables were examined using SPSS for accuracy and missing values. A total of 101 students initially participated in this study. Data were scanned for univariate outliers using standardized residual plots. Cases with too many missing values were dropped. After this cleaning process of the data, 81 cases remained for analysis. Among the 81 cases, six cases were found to have at least one incomplete questionnaire, but were kept for analyses that did not require all questionnaires. Characteristics of the sample are shown in Table 3.

Table 3.

Characteristics of the Sample

Characteristics of Sample		**N (= 81)**
Gender	Male	23
	Female	58
Age	19	57
	20	8
	21	8
	22	3
	23	3
	24	1
Race/Ethnicity	Caucasian	72
	African-American	5
	Hispanic	2
	Asian or Pacific Islander	1
	Middle Eastern	1
College Classification	Freshman	64
	Sophomore	3
	Junior	7
	Senior	7
Academic Majors	Business	35
	Literal Arts	21
	Nursing	12
	Education	9
	Counseling	2
	Undecided	2
Enrollment in Courses that utilized WBI	Yes	21
	No	60
Completion of WBI Course(s)	Yes	11
	No	70

Among the 21 participants who enrolled in courses that utilized WBI, eleven of them enrolled in only one course that utilized WBI, five enrolled in two courses that utilized WBI, four enrolled in three courses that utilized WBI, and only 1 enrolled in four courses that utilized WBI. As for completion of WBI course(s), 9 (out of 11) participants who completed WBI course(s) only completed one WBI course, whereas, only 1 participant completed two WBI courses, and only 1 participant completed three WBI courses.

In addition, overall, 56.1% of the participants experienced a negative attitude change towards computers, 6.4% experienced no attitude change towards computers, and the remaining 38.5% experienced a positive attitude change toward computers. As for attitude change towards mathematics, 42.6% of the participants experienced a negative attitude change, 3.2% experienced no attitude change, and the remaining 54.2% experienced a positive attitude change. Finally, 47 % of the participants in the experimental group were satisfied with WBI and 47% of the participants in the same group were not satisfied with WBI. The remaining 6% were neutral.

Research Question One

Does the presence of animated agents with verbal audio in WBI affect mathematics achievement and attitudes toward mathematics and computers among college students based on gender, college classification, and WBI experiences?

Independent variables (gender, college classification, and WBI experiences) were examined using ANOVA and MANOVA techniques to investigate statistical relationships among those three variables and dependent variables (student mathematics achievement, attitude towards mathematics difference scores, and attitude towards computers differences scores)[10] to answer this question. First, one-way ANOVAs were executed to investigate the significant differences among each independent variable on

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[10] The attitude difference score represents a change in attitude.

mathematics achievement (practice effect and application effect) and attitude change towards mathematics and computers. Then, two-way ANOVAs were conducted to examine the effects of animated agents with verbal audio in WBI on mathematics achievement and attitude change toward mathematics and computers based on gender, college classification, and WBI experiences by group type. Finally, two-way MANOVAs were performed to test whether or not if there exist significance differences between the two groups on the combination of different dependent variables.

Group Type

Adam implements a many-to-one instructional model, which makes many different types of instruction available for one lesson module and keeps track of student activities, such as time of log in and log out and number of instructions needed to complete one lesson. In this study, a significant number of participants were not required to complete more than one instruction for a lesson. Thus, the number of instruction completed per lesson module was not measured against mathematics achievement and attitude change toward mathematics and computers.

However, there was a significance difference between the two groups [See Table 4] when investigating the practice effect [$F = 3.990$, $p < .05$] and attitude change toward mathematics [$F = 4.733$, $p < .05$]. The experimental group significantly outperformed the control group on all lesson assessments which measured practice effect. However, there existed no significance differences between the two groups when investigating attitude change toward computers [$F = .381$, $p > .05$] and the average score of the two exam problems [$F = .672$, $p > .05$] which measured application effect. Thus, the two groups experienced similar changes in attitudes toward computers and performance on exam problems that were related to the content delivered through *Adam*.

Table 4.

ANOVA – Group Type – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change toward Computers

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Practice Effect	Between Groups	6.789	1	6.789	3.990	.049*
	Within Groups	132.708	78	1.701		
Application Effect	Between Groups	.702	1	.702	.672	.415
	Within Groups	80.432	77	1.045		
Attitude Change towards Computers	Between Groups	.021	1	.021	.381	.540
	Within Groups	3.323	60	.055		
Attitude Change towards Mathematics	Between Groups	.385	1	.385	4.733	.033*
	Within Groups	5.046	62	.081		

*p < .05

Gender

There were no significance differences [See Table 5] among gender when investigating the practice effect [F = .002, p > .05], attitude change toward mathematics [F = .251, p > .05] and computers [F = .032, p > .05], and the application effect [F = 2.273, p > .05]. Based on these results, one can assume that gender differences in mathematics achievement and attitude change toward mathematics and computers do not exist.

Table 5.

ANOVA – Gender – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change towards Computers

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Practice Effect	Between Groups	.004	1	.004	.002	.961
	Within Groups	139.493	78	1.788		
Application Effect	Between Groups	2326	1	2.326	2.273	.136
	Within Groups	78.808	77	1.023		
Attitude Change towards Computers	Between Groups	.002	1	.002	.032	.858
	Within Groups	3.342	60	.056		
Attitude Change towards Mathematics	Between Groups	.022	1	.022	.251	.618
	Within Groups	5.410	62	.087		

$*p < .05$

Furthermore, because the categorical cell sizes for gender were not proportional, the Welch's test of equality of means was executed to see if the variance for each dependent variable was homogeneous. According to these results [See Table 6], the variances were heterogeneous. Thus, these findings are not legitimated.

Table 6.

Welch Tests of Equality of Means - Gender

	Statistic^a	**df1**	**df2**	**Sig.**
Practice Effect	.003	1	52.921	.955
Application Effect	2.099	1	37.777	.156
Attitude Change towards Computers	.034	1	17.304	.855
Attitude Change towards Mathematics	.497	1	29.590	.486

a. Asymptotically F distributed.

$*p < .05$

College Classification

There were no significance differences [See Table 7] among college classification when investigating the practice effect [F = .604, p > .05], attitude change toward mathematics [F = .885, p > .05] and computers [F = 1.147, p > .05], and the application effect [F = 1.705, p > .05]. With this understanding, one can conclude that college classification is not a significant predictor of mathematics achievement and attitude change towards mathematics and computers.

Table 7.

ANOVA – College Classification – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change towards Computers

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Practice Effect	Between Groups	3.251	3	1.084	.604	.614
	Within Groups	136.246	76	1.793		
Application Effect	Between Groups	5.179	3	1.726	1.705	.173
	Within Groups	75.955	75	1.013		
Attitude towards Computers	Between Groups	.187	3	.062	1.147	.338
	Within Groups	3.157	58	.054		
Attitude towards Mathematics	Between Groups	.230	3	.077	.885	.454
	Within Groups	5.201	60	.087		

*p < .05

Furthermore, because the categorical cell sizes for college classification were not proportional, the Welch’s test of equality of means was executed to see if the variance for each dependent variable was homogeneous. According to these results [See Table 8], the variances were heterogeneous. Thus, these findings are not legitimated.

Table 8.

Welch Tests of Equality of Means – College Classification

	Statistic[a]	df1	df2	Sig.
Practice Effect	1.012	3	7.756	.438
Application Effect	2.872	3	7.607	.107
Attitude Change towards Computers	1.095	3	4.132	.446
Attitude Change towards Mathematics	3.930	3	5.461	.080

a Asymptotically F distributed.
*p < .05

WBI Experiences

WBI experiences was measured using the number of courses the participants enrolled in that utilized WBI (enrollment in courses that utilized WBI) and the number of courses the participants completed that were delivered via the Web (completion of WBI courses). According to results from analyses, there were no significance differences based on enrollment in courses that utilized WBI [See Table 9] when investigating the practice effect [F = .309, p > .05], attitude change toward mathematics [F = .206, p > .05] and computers [F = .262, p > .05], and the application effect [F = .000, p > .05].

Table 9.

ANOVA – Enrollment in Courses that utilized WBI – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change towards Computers

		Sum of Squares	df	Mean Square	F	Sig.
Practice Effect	Between Groups	.551	1	.551	.309	.580
	Within Groups	138.946	78	1.781		
Application Effect	Between Groups	.000	1	.000	.000	.999
	Within Groups	81.134	77	1.054		
Attitude Change towards Computers	Between Groups	.011	1	.011	.206	.652
	Within Groups	3.333	60	.056		
Attitude Change towards Mathematics	Between Groups	.023	1	.023	.262	.611
	Within Groups	5.409	62	.087		

*p < .05

In addition, because the categorical cell sizes for enrollment in courses that utilized WBI were not proportional, the Welch's test of equality of means was executed to see if the variance for each dependent variable was homogeneous. According to these results [See Table 10], the variances were heterogeneous. Thus, these findings are not legitimated.

Table 10.

Welch Tests of Equality of Means – Enrollment in Courses that utilized WBI

	Statistic[a]	**df1**	**df2**	**Sig.**
Application Effect	.000	1	37.841	.999
Practice Effect	.402	1	42.178	.530
Attitude Change towards Computers	.131	1	17.814	.721
Attitude Change towards Mathematics	.307	1	26.600	.584

a Asymptotically F distributed.
*p < .05

Furthermore, results from analyses investigating significant difference based on completion of WBI courses [See Table 11] indicated no significant differences with the practice effect [F = .004, p > .05], attitude change towards mathematics [F = .818, p > .05] and computers [F = .270, p > .05]. However, the application effect [F = 7.737, p < .05] was significant. Thus, based on these findings, it can be concluded that WBI experiences are not significant predictors of mathematics achievement (when investigating the practice effect) and attitude change towards mathematics and computers. However, completion of WBI courses was declared a significant predictor of mathematics achievement when investigating the application effect.

Table 11.

ANOVA – Completion of WBI Courses – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change towards Computers

		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Practice Effect	Between Groups	.008	1	.008	.004	.948
	Within Groups	137.037	77	1.780		
Application Effect	Between Groups	7.469	1	7.469	7.737	.007*
	Within Groups	73.362	76	.965		
Attitude towards Computers	Between Groups	.046	1	.046	.818	.369
	Within Groups	3.298	59	.056		
Attitude towards Mathematics	Between Groups	.024	1	.024	.270	.605
	Within Groups	5.385	61	.088		

*p < .05

Finally, because the categorical cell sizes for enrollment in courses that utilized WBI were not proportional, the Welch's test of equality of means was executed to see if the variance for each dependent variable was homogeneous. According to these results [See Table 12], the variances were heterogeneous except for the application effect [$F_A = 5.243$, $p < .05$]. Thus, there exists a significant difference, based on completion of WBI courses, on application effect.

Table 12.

Welch Tests of Equality of Means – Completion of WBI Courses

	Statistic[a]	**df1**	**df2**	**Sig.**
Application Effect	5.243	1	11.989	.041*
Comprehension Improvement Overall	.005	1	12.630	.943
CAS Difference Score	.650	1	8.626	.442
MAI Difference Score	.205	1	8.469	.662

a Asymptotically F distributed (F_A).
*p < .05

To investigate the effects of animated agents with verbal audio in WBI on mathematics achievement and attitude change toward mathematics and computers more thoroughly, a series of two-way ANOVAs were executed to verify if the incorporation of animated agents with verbal audio in WBI can improve mathematics achievement and positive attitude change toward mathematics and computers. Each of the dependent variables was examined separately against the independent variables with an interaction for group type.

Gender by Group Type

This group of analyses investigated the relationship of gender to mathematics achievement and attitude change towards mathematics and computers. Each of the dependent variables was examined separately against the independent variable, gender, with an interaction for group type.

To examine the effects of animated agents with verbal audio on mathematics achievement based on gender, a 2 [Gender: male, female] by 2 [Group type: experimental, control] two-way ANOVA was performed. Results of this ANOVA [See Table 13] show that the main effect for group type [$F = 4.080$, $p < .05$] reached statistical significance when investigating practice effect, suggesting that there exist gender differences between the two groups. The main effects, however, for gender [$F = .002$, $p > .05$] and the interaction between gender and group type [$F = .327$, $p > .05$] failed to reach statistical significance. Additionally, the main effects for group type [$F = .704$, $p > .05$], gender [$F = 2.041$, $p > .05$], and the interaction between gender and group type [F = .096, p > .05] failed to reach statistical significance when investigating the application effect.

Table 13.

ANOVA – Gender by Group Type – Mathematics Achievement

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Practice Effect	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		
Application Effect	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

Means and standard deviations are shown in Table 14.

Table 14.

Means and Standard Deviations – Gender by Group Type – Mathematics Achievement

	Group Assignment	Gender	Mean	Std. Deviation
Practice Effect	Experimental Group	Male	1.9000	.69921
		Female	1.6964	1.32175
		Total	1.7500	1.18407
	Control Group	Male	1.0417	1.11719
		Female	1.2167	1.51818
		Total	1.1667	1.40412
Application Effect	Experimental Group	Male	2.8500	1.26307
		Female	3.1346	1.07278
		Total	3.0556	1.13697
	Control Group	Male	2.5577	1.07982
		Female	3.0000	.98310
		Total	2.9525	1.01990

The level of immediate mathematics achievement was higher among students who used *Adam* to complete lesson modules [experimental group] than among those who used a paper-based version [control group]. As for gender, in the experimental group, the males slightly outperformed females; while in the control group, the females slightly outperformed the males.

The interaction between gender and group type [See Figure 3], however, shows a cross-over interaction, explaining that, belonging to a particular group does not guarantee higher levels of immediate mathematics achievement depending on gender.

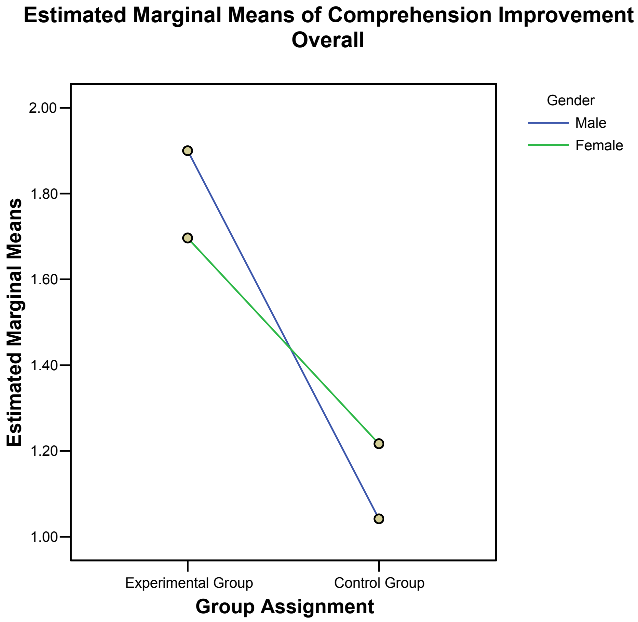

Figure 3. Cross-over Interaction – Gender by Group Type - Achievement.

Results from a two-way ANOVA [See Table 15] that examined the gender instances by group type showed that the main effects for group type [F = 1.615, p > .05], gender [F = .150, p > .05] and their interaction [F = .219, p > .05] failed to reach statistical significance when investigating attitude change towards mathematics. Males and females in both groups experienced similar and low attitude change towards mathematics. However, participants in the experimental group experienced a positive change in their attitude towards mathematics, while the control group, experienced a negative change.

Table 15.

ANOVA – Gender by Group Type – Attitude Change towards Mathematics

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Group Type	.135	1	.135	1.615	.209
Error (Group Type)	5.046	62	.081		
Gender	.013	1	.013	.150	.700
Group Type * Gender	.018	1	.018	.219	.641
Error	5.022	60	.084		

*p < .05

Means and standard deviations are shown in Table 16.

Table 16.

Means and Standard Deviations – Gender by Group Type – Attitude Change towards Mathematics

Group Assignment	**Gender**	**Mean**	**Std. Deviation**
Experimental Group	Male	.0362	.20313
	Female	.1194	.22582
	Total	.1079	.22132
Control Group	Male	-.0419	.17081
	Female	-.0498	.36533
	Total	-.0480	.32875

Furthermore, Figure 4 provides a graphical representation of how belonging to a particular group does not guarantee change of attitude toward mathematics based on gender.

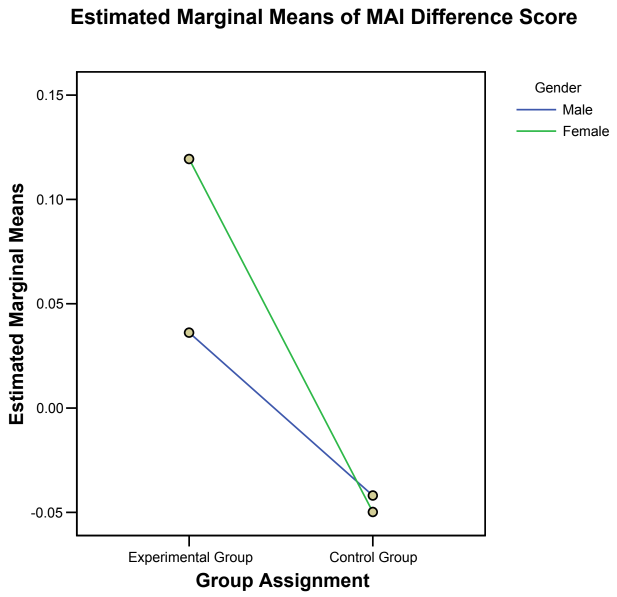

Figure 4. Cross-over Interaction – Gender by Group Type and Attitude Change towards Mathematics.

Finally, the main effects for group type [F = .881, p > .05], gender [F = .012, p > .05] and their interaction [F = .565, p > .05] failed to reach statistical significance [See Table 17] when investigating attitude change towards computers. Males and females in both groups experienced similar and low attitude change towards computers. However, the males in the control group experienced a positive change in their attitude toward computers, while the experimental group and the females in the control group experienced a negative change.

Table 17.

ANOVA – Gender by Group Type – Attitude Change towards Computers

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.050	1	.050	.881	.352
Error (Group Type)	3.323	60	.055		
Gender	.001	1	.001	.012	.914
Group Type * Gender	.032	1	.032	.565	.455
Error	3.290	58	.057		

*p < .05

Means and standard deviations are shown in Table 18.

Table 18.

Means and Standard Deviations – Gender by Group Type – Attitude Change towards Computers

Group Assignment	Gender	Mean	Std. Deviation
Experimental Group	Male	-.1313	.24696
	Female	-.0622	.22330
	Total	-.0720	.22329
Control Group	Male	.0046	.21855
	Female	-.0471	.25503
	Total	-.0350	.24475

In addition, Figure 5 demonstrates graphically how belonging to a particular group does not guarantee change of attitude toward computers based on gender.

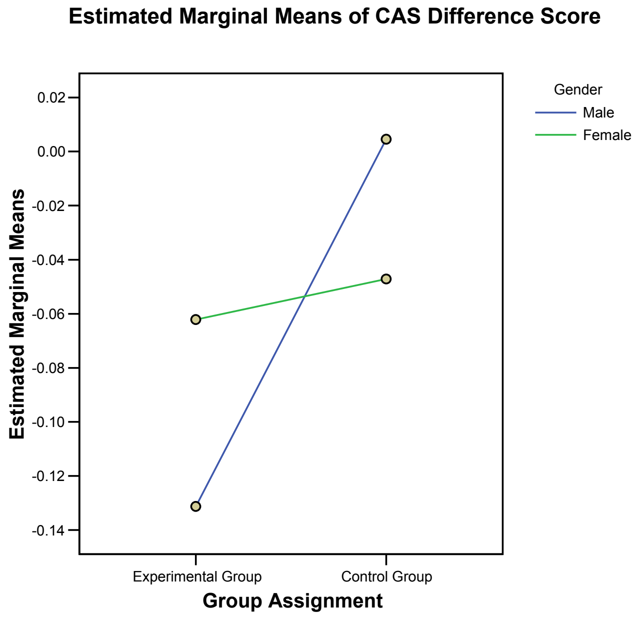

Figure 5. Cross-over Interaction – Gender by Group Type and Attitude Change towards Computers.

College Classification by Group Type

This second group of analyses investigated the relationship of college classification to mathematics achievement and attitude change towards mathematics and computers. Each of the dependent variables was examined separately against the independent variable, college classification, with an interaction for group type.

Results [See Table 19] showed that the main effects for group type ([F = .472, p > .05]; [F = .010, p > .05]), for college classification ([F = .802, p > .05]; [F = 1.531, p > .05]) and their interaction ([F = .635, p > .05]; [F = .094, p > .05]) failed to reach statistical significance when investigating immediate mathematics achievement and application effect, respectively. These results indicated that in both groups, all college classifications' mathematics achievement were similar. However, the freshman class slightly outperformed the other three classes in the experimental group, while the junior class outperformed the other three classes in the control group[11].

Table 19.

ANOVA – College Classification by Group Type – Mathematics Achievement

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Practice Effect	Group Type	.826	1	.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		
Application Effect	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

Means and standard deviations are shown in Table 20.

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[11] There was only one participant in the control group that was a sophomore.

Table 20.

Means and Standard Deviations – College Classification by Group Type – Mathematics Achievement

	Group Assignment	**College Classification**	**Mean**	**Std. Deviation**
Practice Effect	Experimental Group	Freshman	1.9333	1.22990
		Sophomore	1.2500	.35355
		Junior	1.0000	.86603
		Senior	1.0000	.86603
		Total	1.7500	1.18407
	Control Group	Freshman	1.1818	1.50944
		Sophomore	.0000	.
		Junior	1.5000	.91287
		Senior	1.0000	1.08012
		Total	1.1667	1.40412
Application Effect	Experimental Group	Freshman	3.1750	.88608
		Sophomore	2.5000	
		Junior	2.7500	.35355
		Senior	2.2500	.43301
		Total	3.0556	.86419
	Control Group	Freshman	2.9853	1.12132
		Sophomore	2.7500	
		Junior	2.3750	.47871
		Senior	2.3750	1.79699
		Total	2.8663	1.13697

Figure 6 provides a graphical representation of how belonging to a particular group does not guarantee improvement in mathematics achievement based on college classification.

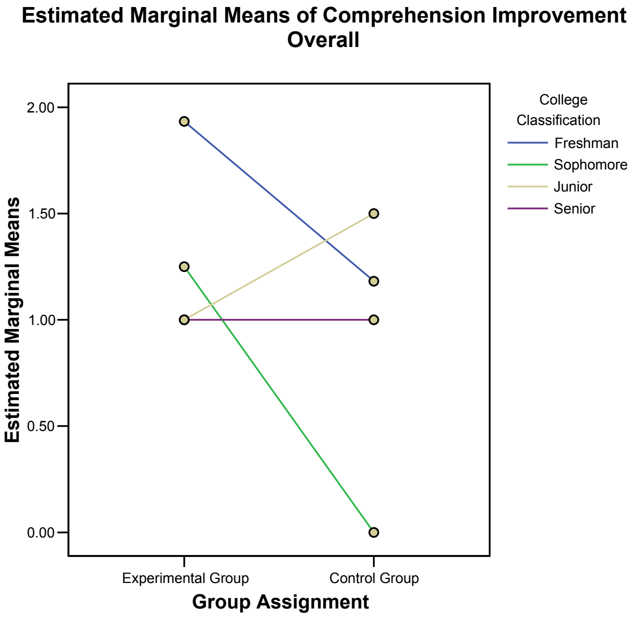

Figure 6. Cross-over Interaction – College Classification by Group Type - Achievement.

As for attitude change toward mathematics, results [See Table 21] showed that the main effects for group type [F = 7.197, p < .05] reached statistical significance, while main effects for college classification [F = .347, p > .05] and their interaction [F = .1.768, p > .05] failed to reach statistical significance.

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 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.

Table 21.

ANOVA – College Classification by Group Type – Attitude Change towards Mathematics

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

Means and standard deviations are shown in Table 22.

Table 22.

Means and Standard Deviations – College Classification by Group Type – Attitude Change towards Mathematics

Group Assignment	College Classification	Mean	Std. Deviation
Experimental Group	Freshman	.0540	.16437
	Sophomore	.3229	.10312
	Junior	.2708	.44537
	Senior	.1786	.29645
	Total	.1079	.22132
Control Group[12]	Freshman	-.0120	.35506
	Junior	-.1094	.12658
	Senior	-.2292	.23632
	Total	-.0480	.32875

Figure 7 provides a graphical representation of the relationship of college classification to attitude change toward mathematics between the two groups. As shown in the figure, a cross-over interaction exists between the freshman class and the junior

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[12] The data representing attitude change toward mathematics for the sophomore in the control group were not calculated due to incompletion of survey.

and senior classes. Therefore, a freshman belonging to a particular group does not guarantee a positive (or negative) attitude change towards mathematics. However, the slope performance between the junior class and the senior class are very similar; that is, there is no significant difference in attitude change towards mathematics among the junior and senior classes.

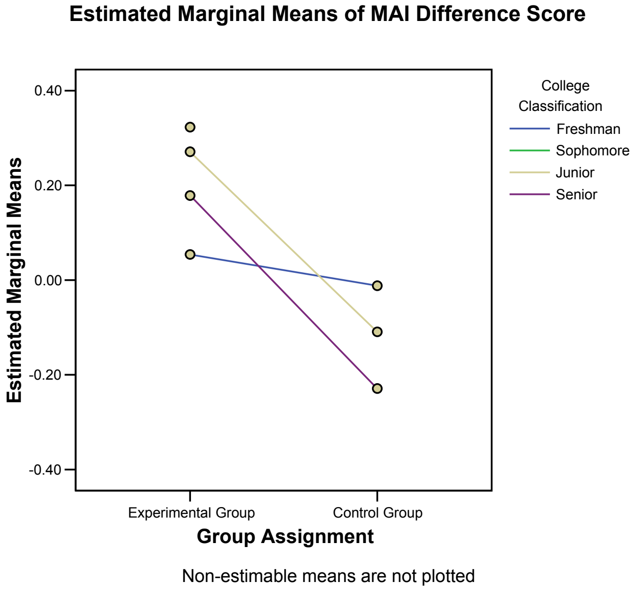

Figure 7. Cross-over Interaction and Slope Display – College Classification by Group Type - Attitude Change toward Mathematics.

Results from ANOVA performed on attitude change towards computers [See Table 23] showed that main effects for group type [F = .969, p > .05], college classification [F = .429, p > .05] and their interaction [F = .389, p > .05] failed to reach statistical significance, indicating that all classifications in both groups experienced similar and low attitude change towards computers. However, the junior class in the control group experienced a greater change in their attitude toward computers than the others classes in that group, while the sophomore class in the experimental group experienced a greater change in attitude toward computers in that particular group [See Table 24].

Table 23.

ANOVA – College Classification by Group Type – Attitude Change towards Computers

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Group Type	.000	1	.000	.001	.969
College Classification	.154	3	.051	.936	.429
Group Type * College Classification	.105	2	.053	.961	.389
Error	3.009	55	.055		

*p < .05

Means and standard deviations are shown in Table 24.

Table 24.

Means and Standard Deviations – College Classification by Group Type – Attitude Change towards Computers

Group Assignment	**College Classification**	**Mean**	**Std. Deviation**
Experimental Group	Freshman	-.0828	.17089
	Sophomore	.1375	.22981
	Junior	-.0583	.11273
	Senior	-.1536	.54884
	Total	-.0720	.22329
Control Group[13]	Freshman	.0014	.24588
	Junior	-.2375	.19419
	Senior	-.0688	.22302
	Total	-.0350	.24475

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[13] Data representing attitude change toward computers for the sophomore in the control group were not calculated due to incompletion of survey.

Figure 8 provides a graphical representation on how belonging to a particular group does not guarantee a positive (or negative) attitude change towards computers. However, the slope performance between the freshman class and the senior class are very similar; meaning, there is no significant difference in attitude change towards computers among the freshman and senior classes.

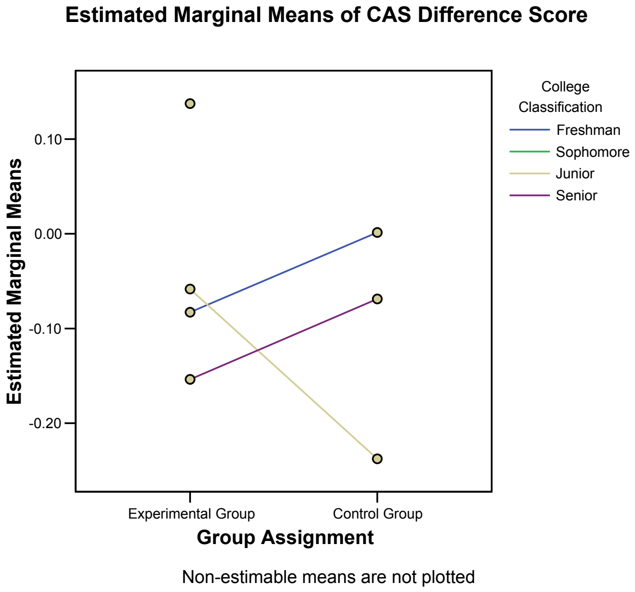


Figure 8. Cross-over Interaction and Slope Display – College Classification by Group Type - Attitude Change towards Computers.

WBI Experiences by Group Type

The next group of analyses investigated the relationship of WBI experiences [enrollment in a course that utilized WBI and completion of WBI course(s)] to mathematics achievement and attitude change towards mathematics and computers. Each of the dependent variables was examined separately against the independent variable, WBI experiences, with an interaction for group type.

To examine the enrollment in courses that utilized WBI instances by group type, a 2 [Enrollment in courses that utilized WBI: yes, no] by 2 [Group type: experimental, control] two-way ANOVA was performed on mathematics achievement. Results of this ANOVA [See Table 25] show that main effects for group type [F = .147, F = .025, p > .05] enrollment in courses that utilized WBI [F = .738, F = .023, p > .05] and their interaction [F = .778, F = 1.149, p > .05] failed to reach statistical significance indicating that both groups improved their achievement regardless if they enrolled in a course that utilized WBI or not. In addition, the experimental group slightly outperformed the control group regardless of enrollment in courses that utilized WBI [See Table 22].

Table 25.

ANOVA – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement

	Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Practice Effect	Group Type	3.742	1	3.742	2.148	.147
	Enrollment in Courses that utilized WBI	.197	1	.197	.113	.738
	Group Type * Enrollment in Courses that utilized WBI	.140	1	.140	.080	.778
	Error	132.432	76	1.743		
Application Effect	Group Type	.026	1	.026	.025	.875
	Enrollment in Courses that utilized WBI	.025	1	.025	.023	.879
	Group Type * Enrollment in Courses that utilized WBI	1.213	1	1.213	1.149	.287
	Error	79.204	75	1.056		

*p < .05

Means and standard deviations are shown in Table 26.

Table 26.

Means and Standard Deviations – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement

	Group Assignment	**Enrollment in course(s) that utilized WBI**	**Mean**	**Std. Deviation**
Practice Effect	Experimental Group	Yes	1.5714	.73193
		No	1.7903	1.27000
		Total	1.7500	1.18407
	Control Group	Yes	1.1538	1.23127
		No	1.1724	1.49568
		Total	1.1667	1.40412
Application Effect	Experimental Group	Yes	2.7857	1.11311
		No	3.1207	1.15867
		Total	3.0556	1.13697
	Control Group	Yes	3.0357	.97346
		No	2.7845	1.04447
		Total	2.8663	1.01990

Enrollment in courses that utilized WBI by group type's interaction [See Figure 9] showed that, even though mathematics achievement improved for each group for enrollment status in courses that utilized WBI, the slope performance of each enrollment status is very similar to one another. This indicates that there is no significant difference in achievement among group type and enrollment in courses that utilized WBI.

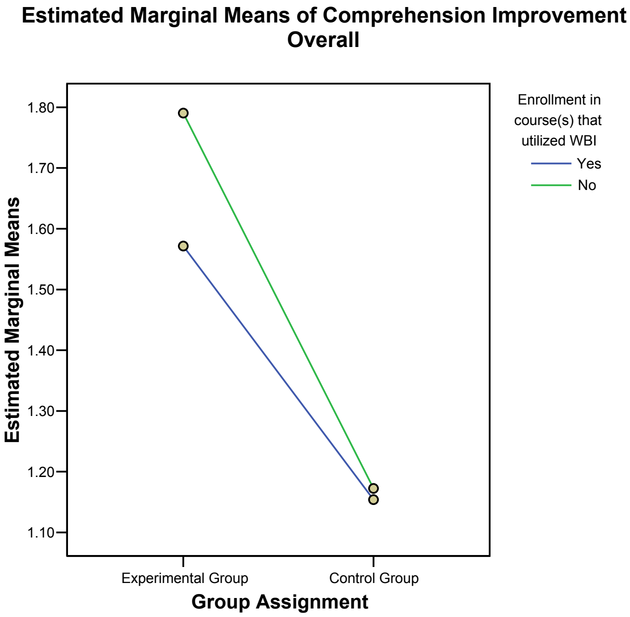


Figure 9. Slope Display – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement.

To examine the completion of WBI course(s) instances by group type, a 2 [Completion of WBI course(s): yes, no] by 2 [Group type: experimental, control] two-way ANOVA was performed on mathematics achievement. Results of this ANOVA [See Table 27] showed that main effects for group type [F = 1.618, F = .821, p > .05], completion of WBI course(s) [F = .028, p > .05] and their interaction [F = .028, F = .354, p > .05] failed to reach statistical significance indicating that both groups improved their mathematics achievement, regardless if they completed WBI course(s). However, even though the analysis showed that the main effect for completion of WBI courses [F = 6.108, p < .05] was significant for application effect, it is not truly significant because the completion of WBI courses cell size was not proportional. In addition, the experimental group slightly outperformed the control group, and mathematics achievement in the experimental group was identical [See Table 28].

Table 27.

ANOVA – Completion of a WBI course by Group Type – Mathematics Achievement

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Practice Effect	Group Type	2.786	1	2.786	1.618	.207
	Completion of WBI Courses	.047	1	.047	.028	.869
	Group Type * Completion of WBI Courses	.047	1	.047	.028	.869
	Error	129.150	75	1.722		
Application Effect	Group Type	.805	1	.805	.821	.368
	Completion of WBI Courses	5.988	1	5.988	6.108	.016*
	Group Type * Completion of WBI Courses	.347	.1	.347	.354	.554
	Error	72.546	74	.980		

*p < .05

Means and standard deviations are shown in Table 28.

Table 28.

Means and Standard Deviations – Completion of WBI course(s) by Group Type – Mathematics Achievement

	Group Assignment	Completion_WBI course	Mean	Std. Deviation
Practice Effect	Experimental Group	Yes	1.7500	.86603
		No	1.7500	1.22629
		Total	1.7500	1.18407
	Control Group	Yes	1.2500	1.40535
		No	1.1000	1.40796
		Total	1.1220	1.39096
Application Effect	Experimental Group	Yes	2.5000	1.08012
		No	3.1250	.82794
		Total	3.0556	.86419
	Control Group	Yes	2.0000	1.35401
		No	3.0214	1.04031
		Total	2.8512	1.14639

Figure 10 shows graphically that while mathematics achievement improved for each group for completion status in WBI courses, the slope performance is very similar among completion of WBI courses. Thus, indicating that there is no significant difference in achievement among group type and completion of WBI courses.

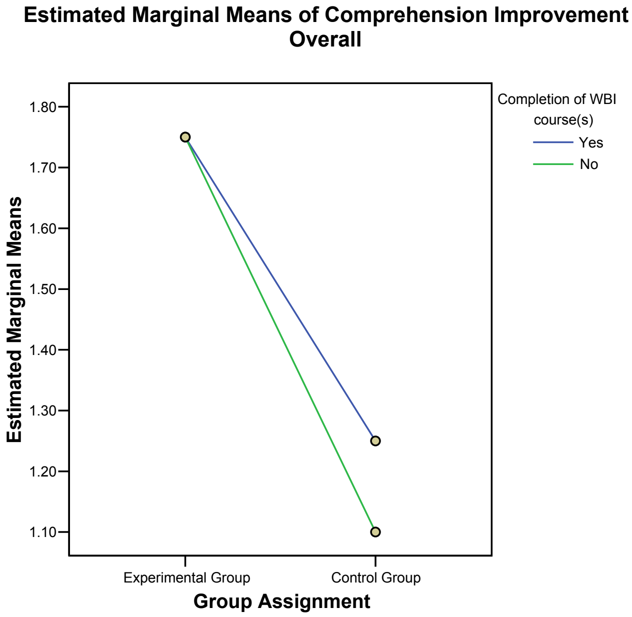


Figure 10. Slope Display – Completion of WBI Course(s) by Group Type – Achievement.

As for attitude change toward mathematics, results from ANOVA [See Table 29] showed that the main effect for group type [F = 4.576, p < .05] reached statistical significance, while main effects for enrollment in courses that utilized WBI [F = .261, p > .05] and their interaction [F = .335, p > .05] failed to reach statistical significance.

Table 29.

ANOVA – Enrollment in Courses that utilized WBI by Group Type – Attitude Change towards Mathematics

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

Means and standard deviations are shown in Table 30.

Table 30.

*Means and Standard Deviations – Enrollment in Courses that utilized WBI by Group Type – Attitude Change towards Mathematic*s

Group Assignment	Enrollment in course(s) that utilized WBI	Mean	Std. Deviation
Experimental Group	Yes	.1123	.23757
	No	.1065	.22176
	Total	.1079	.22132
Control Group	Yes	-.1198	.24594
	No	-.0267	.35070
	Total	-.0480	.32875

As expected, the level of attitude change towards mathematics was higher for students in the experimental group than for those in the control group. For enrollment in courses that utilized WBI, students who enrolled in courses that utilized WBI in the experimental group experienced a more positive attitude change in mathematics than those in the experimental group who did not. Students in the control group who enrolled in courses that utilized WBI experienced a more negative attitude change in mathematics than those who did not.

Figure 11 provides a graphical representation of the interaction, which is a cross-over interaction, between enrollment in courses that utilized WBI and group type. Thus, enrollment in courses that utilized WBI does not guarantee if a student's attitude towards mathematics will change significantly.

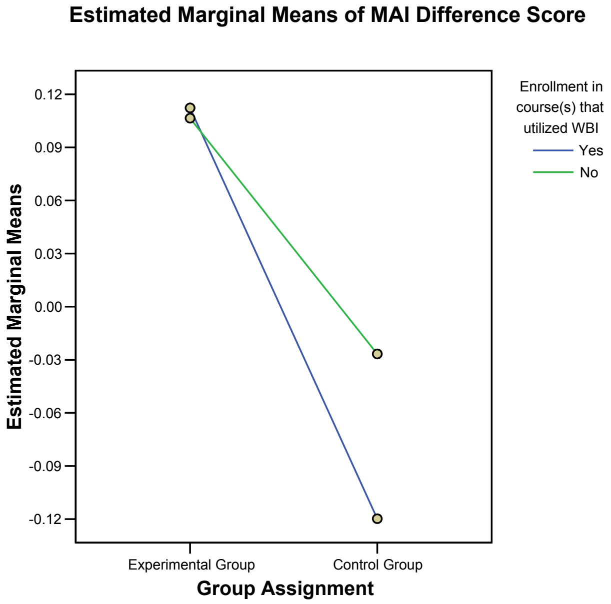


Figure 11. Cross-over Interaction – Enrollment in Courses that utilized WBI by Group Type – Attitude Change toward Mathematics.

To examine the completion of a WBI course instances by group type on attitude change toward mathematics, a 2 by 2 two-way ANOVA was performed. Results of this ANOVA [See Table 31] showed that main effects for group type [F = 8.468, p < .05] reached a statistical significance, while, the main effects of completion of a WBI course

[F = .348, p > .05] and their interaction [F = 3.852, p > .05] failed to reach statistical significance.

Table 31.

ANOVA – Completion of WBI Courses by Group Type – Attitude Change towards Mathematics

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

Means and standard deviations are shown in Table 32.

Table 32.

Means and Standard Deviations – Completion of WBI Courses by Group Type – Attitude Change toward Mathematics

Group Assignment	Completion of WBI course(s)	Mean	Std. Deviation
Experimental Group	Yes	.2344	.24731
	No	.0876	.21542
	Total	.1079	.22132
Control Group	Yes	-.2865	.20297
	No	-.0136	.33642
	Total	-.0457	.33342

As expected again, the level of attitude change towards mathematics was more positive for students in the experimental group than for those in the control group. For completion of WBI courses, the students who completed WBI courses in the experimental group experienced a more positive attitude change in mathematics than those in the experimental group who did not. Students in the control group who did complete WBI courses experienced a more negative attitude change in mathematics than those who did not.

Figure 12 provides a graphical representation on why completing WBI courses does not guarantee, if a student's attitude towards mathematics will change significantly.

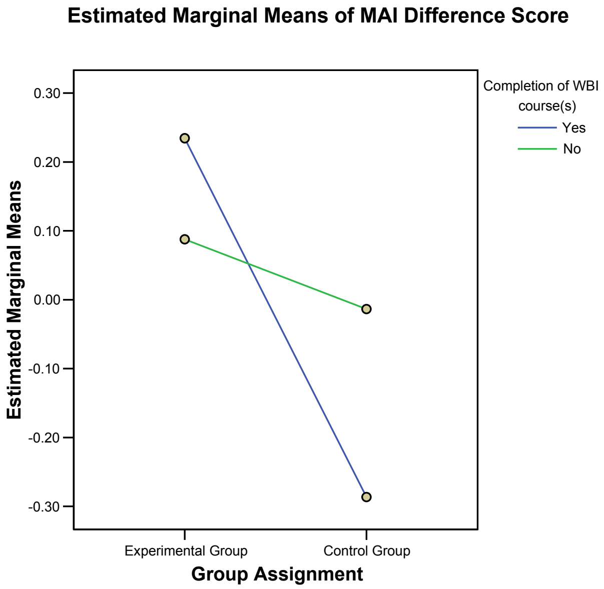


Figure 12. Cross-over Interaction – Completion of WBI Courses by Group Type – Attitude Change towards Mathematics.

Finally, a two-way ANOVA was performed on attitude change towards computers to examine the enrollment in courses that utilized WBI instances by group type. Results from this ANOVA [See Table 33] showed that the main effects for group type [F = .688, p > .05], enrollment in courses that utilized WBI [F = .234, p > .05] and their interaction [F = .372, p > .05] failed to reach statistical significance.

Table 33.

ANOVA – Enrollment in Courses that utilized WBI by Group Type – Attitude Change toward Computers

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.039	1	.039	.688	.410
Enrollment in Courses that utilized WBI	.013	1	.013	.234	.631
Group Type * Enrollment in Courses that utilized WBI	.021	1	.021	.372	.544
Error	3.291	58	.057		

*p < .05

Means and standard deviations are shown in Table 34.

Table 34.

Means and Standard Deviations – Enrollment in Courses that utilized WBI by Group Type – Attitude Change towards Computers

Group Assignment	Enrollment in course(s) that utilized WBI	Mean	Std. Deviation
Experimental Group	Yes	-.1301	.30269
	No	-.0527	.19557
	Total	-.0720	.22329
Control Group	Yes	-.0281	.34446
	No	-.0371	.21408
	Total	-.0350	.24475

The main effect of the group type and the main effect of enrollment in courses that utilized WBI indicate that both groups' attitudes toward computers changed negatively regardless of enrollment in courses that utilized WBI. However, students in the experimental group who enrolled in courses that utilized WBI experienced a more negative change in attitudes toward computers than the students in the same group who did not enroll in courses that utilized WBI and students in the control group.

Figure 13 shows a cross-over interaction between enrollment in courses that utilized WBI and group type when investigating attitude change toward computers. Thus, enrollment in courses that utilized WBI does not guarantee if a student's attitude towards computers will change significantly.

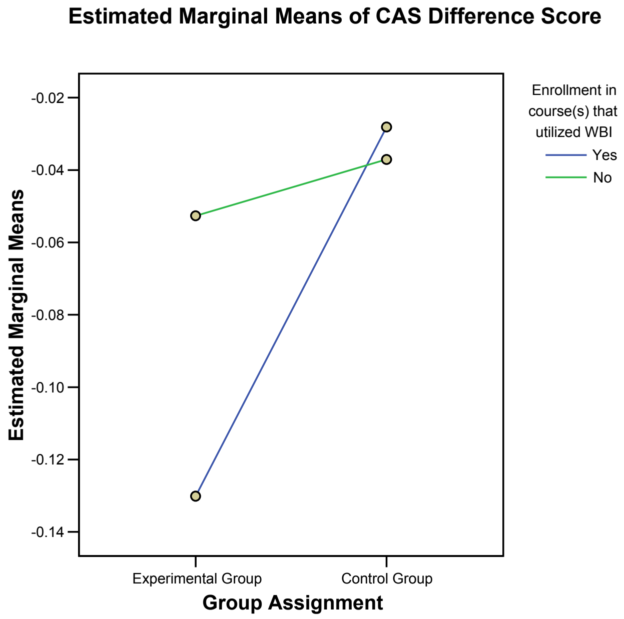


Figure 13. Cross-over Interaction – Enrollment in Courses that utilized WBI by Group Type – Attitude Change towards Computers.

As for completion of WBI courses, results [See Table 35] showed that the main effects for group type [F = 1.922, p > .05] and completion of WBI courses [F = .786, p > .05] failed to reach statistical significance. However, their interaction [F = 5.985, p <. 05] reached a statistical significance. Students in the control group who completed

WBI courses experienced a more negative change in attitudes toward computers than the students in the same group who did not enroll in courses that utilized WBI and students in the experimental group [See Table 36].

Table 35.

ANOVA – Completion of WBI courses by Group Type – Attitude Change toward Computers

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Group Type	.100	1	.100	1.922	.171
Completion of WBI Courses	.041	1	.041	.786	.379
Group Type * Completion of WBI Courses	.312	1	.312	5.985	.018*
Error	2.967	57	.052		

*p < .05

Means and standard deviations are shown in Table 36.

Table 36.

ANOVA – Completion of WBI courses by Group Type – Attitude Change toward Computers

Group Assignment	Completion of WBI course(s)	Mean	Std. Deviation
Experimental Group	Yes	.0437	.17245
	No	-.0913	.22789
	Total	-.0720	.22329
Control Group	Yes	-.2882	.25865
	No	.0005	.23014
	Total	-.0345	.24853

Figure 14 demonstrates a significant cross-over interaction between completion of WBI courses and group type. Thus, completion of WBI courses can guarantee that a student's attitude towards computers will change significantly.

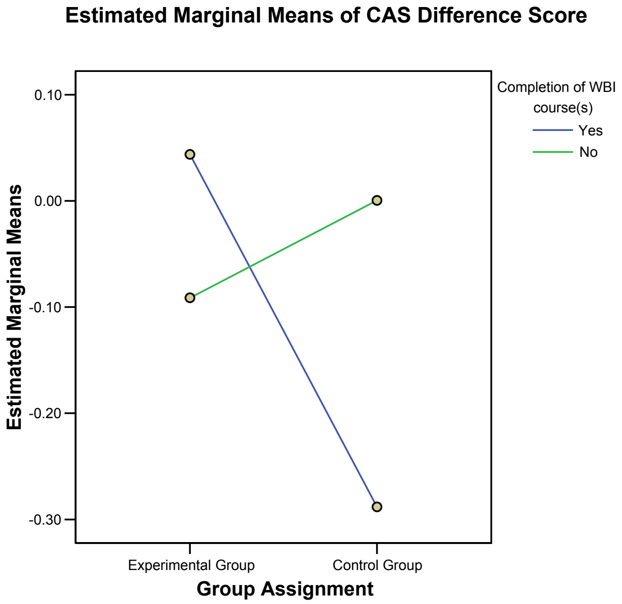


Figure 14. A Significant Cross-over Interaction – Completion of WBI Courses by Group Type - Attitude Change towards Computers.

To assist in verifying the effects of animated agents with verbal audio on mathematics achievement and attitude change towards mathematics and computers, a series of MANOVAs were executed using combinations of the dependent variables and the independent variables. “For maximum protection against finding a statistical significance when there is none, with small samples, Pillai's trace is the preferred statistic” (Walker, 1998). Thus, statistics from the Pillai’s trace multivariate test will be reported. However, results from all four multivariate tests will be displayed in tables.

Gender by Group Type (MANOVA)

The first group of multivariate analyses investigated the mean differences for gender on a combination of mathematics achievement and attitude change towards mathematics and computers. The combination of these dependent variables was examined against the independent variable, gender, with an interaction for group type.

Results from a two-way MANOVA [See Table 37] showed that the main effects for group type [Pillai's Trace = .121, F = 2.579, p > .05], gender [Pillai's Trace = .017, F = .323, p > .05] and their interaction [Pillai's Trace = 0.13, F = .249, p > .05] failed to reach statistical significance of group differences for mathematics achievement and attitude change toward mathematics and computers.

Table 37.

MANOVA – Gender by Group Type – Mathematics Achievement and Attitude Change towards Mathematics and Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.121	2.579	3.000	56.000	.063
Gender	.017	.323	3.000	56.000	.809
Group Type * Gender	.013	.249	3.000	56.000	.862

*p < .05

Furthermore, results from MANOVA [See Table 38] showed that the main effects for group type [Pillai's Trace = .092, F = 2.982, p > .05], gender [Pillai's Trace = .020, F = .608, p > .05] and their interaction [Pillai's Trace = 0.04, F = .108, p > .05] failed to reach statistical significance of group differences for mathematics achievement and attitude change toward mathematics.

Table 38.

MANOVA – Gender by Group Type – Mathematics Achievement and Attitude Change towards Mathematics

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.092	2.982	2.000	59.000	.058
Gender	.020	.608	2.000	59.000	.548
Group Type * Gender	.004	.108	2.000	59.000	.898

*p < .05

Results from MANOVA [See Table 39] also showed that the main effects for group type [Pillai's Trace = .043, F = 1.280, p > .05], gender [Pillai's Trace = .011, F = .325, p > .05] and their interaction [Pillai's Trace = .010, F = .300, p > .05] failed to reach statistical significance of group differences for mathematics achievement and attitude change towards computers.

Table 39.

MANOVA – Gender by Group Type – Mathematics Achievement and Attitude Change towards Computers

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.043	1.280	2.000	57.000	.286
Gender	.011	.325	2.000	57.000	.724
Group Type * Gender	.010	.300	2.000	57.000	.742

*p < .05

Finally, results from MANOVA [See Table 40] showed that group type [Pillai's Trace = .062, F = 1.879, p > .05], gender [Pillai's Trace = .001, F = .040, p > .05] and their interaction [Pillai's Trace = .013, F = .379, p > .05] failed to reach statistical significance of group differences for attitude change towards mathematics and computers.

Table 40.

MANOVA – Gender by Group Type – Attitude Change toward Mathematics and Computers

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.062	1.879	2.000	57.000	.162
Gender	.001	.040	2.000	57.000	.961
Group Type * Gender	.013	.379	2.000	57.000	.686

*p < .05

College Classification by Group Type (MANOVA)

The second group of multivariate analyses investigated the mean differences among college classification on a combination of mathematics achievement and attitude change towards mathematics and computers. The combination of these dependent variables was examined against the independent variable, college classification, with an interaction for group type.

To examine the college classification instances by group type, a 4 [College classification: freshman, sophomore, junior, senior] by 2 [Group Type: Experimental, Control] two-way MANOVA was performed on the combination of achievement and attitude change towards mathematics and computers. Results from this MANOVA [See Table 41] showed that the main effect for group type [Pillai's Trace = .152, F = 3.175, p < .05] reached a significant difference, whereas, the main effects for college classification [Pillai's Trace = .091, F = .576, p > .05] and their interaction

[Pillai's Trace = .093, F = .880, p > .05] failed to reach statistical significance of group differences for mathematics achievement and attitude change towards mathematics and computers.

Table 41.

MANOVA – College Classification by Group Type – Mathematics Achievement, Attitude Change toward Mathematics and Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.152	3.175	3.000	53.000	.031*
College Classification	.091	.576	9.000	165.000	.815
Group Type * College Classification	.093	.880	6.000	108.000	.512

*p < .05

Furthermore, results [See Table 42] showed group type [Pillai's Trace = .134, F = 4.338, p < .05] reached a significant difference for the group differences for mathematics achievement and attitude change toward mathematics, while, the main effects for college classification [Pillai's Trace = .042, F = .412, p > .05] and their interaction [Pillai's Trace = .073, F = 1.087, p > .05] failed to reach statistical significance.

Table 42.

MANOVA – College Classification by Group Type – Mathematics Achievement and Attitude Change toward Mathematics

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.134	4.338	2.000	56.000	.018*
College Classification	.042	.412	6.000	114.000	.870
Group Type * College Classification	.073	1.087	4.000	114.000	.367

*p < .05

Results from MANOVA [See Table 43] also showed that group type [Pillai's Trace = .001, F = .032, p > .05], college classification [Pillai's Trace = .070, F = .663, p > .05] and their interaction [Pillai's Trace = .063, F = .897, p > .05] failed to reach statistical significance for mathematics achievement and attitude change toward computers.

Table 43.

MANOVA – College Classification by Group Type – Mathematics Achievement and Attitude Change towards Computers

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.001	.032	2.000	54.000	.968
College Classification	.070	.663	6.000	110.000	.680
Group Type * College Classification	.063	.897	4.000	110.000	.468

*p < .05

Finally, group type [Pillai's Trace = .131, F = 4.062, p < .05] reached a significant difference for attitude change towards mathematics and computers, while, the main effects for college classification [Pillai's Trace = .070, F = .662, p > .05] and their interaction [Pillai's Trace = .080, F = 1.153, p > .05] failed to reach statistical significance [See Table 44].

Table 44.

MANOVA – College Classification by Group Type – Attitude Change toward Mathematics and Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.131	4.062	2.000	54.000	.023*
College Classification	.070	.662	6.000	110.000	.680
Group Type * College Classification	.080	1.153	4.000	110.000	.336

*p < .05

WBI Experiences by Group Type (MANOVA)

The last group of multivariate analyses investigated the mean differences among WBI experiences [enrollment in courses that utilized WBI and completion of WBI courses] on a combination of mathematics achievement and attitude change towards mathematics and computers. The combination of these dependent variables was examined against the independent variables, enrollment in courses that utilized WBI and completion of WBI courses, separately, with an interaction for group type.

Enrollment in Courses that utilized WBI

To examine the enrollment in courses that utilized WBI instances by group type, a 2 [Enrollment in courses that utilized WBI: yes, no] by 2 [Group type: experimental, control] two-way MANOVA was performed on the combination of achievement, attitude change towards mathematics and computers.

Results from this MANOVA [See Table 45] showed that the main effect for group type [Pillai's Trace = .167, F = 3.733, p < .05] reached a significant difference for mathematics achievement and attitude change toward mathematics and computers, while, the main effects for enrollment in courses that utilized WBI [Pillai's Trace = .006, F = .112, p > .05] and their interaction [Pillai's Trace = .019, F = .369, p > .05] failed to reach statistical significance.

Table 45.

MANOVA – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement, Attitude Change towards Mathematics, and Attitude Change toward Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.167	3.733	3.000	56.000	.016*
Enrollment in Courses that utilized WBI	.006	.112	3.000	56.000	.953
Group Type * Enrollment in Courses that utilized WBI	.019	.369	3.000	56.000	.775

*p < .05

As expected, results from MANOVA [See Table 46] showed group type [Pillai's Trace = .129, F = 4.380, p < .05] reached a significant difference for mathematics achievement and attitude change toward mathematics, while, the main effects for enrollment in courses that utilized WBI [Pillai's Trace = .005, F = .133, p > .05] and their interaction [Pillai's Trace = .013, F = .397, p > .05] failed to reach statistical significance.

Table 46.

MANOVA – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement and Attitude Change toward Mathematics

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.129	4.380	2.000	59.000	.017*
Enrollment in Courses that utilized WBI	.005	.133	2.000	59.000	.875
Group Type * Enrollment in Courses that utilized WBI	.013	.397	2.000	59.000	.674

*p < .05

Results from MANOVA [See Table 47] also showed that the main effect for group type [Pillai’s Trace = .028, F = .828, p > .05], enrollment in courses that utilized WBI [Pillai’s Trace = .005, F = .151, p > .05] and their interaction [Pillai’s Trace = .017, F = .503, p > .05] failed to reach statistical significance for mathematics achievement and attitude change toward computers.

Table 47.

MANOVA – Enrollment in Courses that utilized WBI by Group Type – Mathematics Achievement and Attitude Change towards Computers

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.028	.828	2.000	57.000	.442
Enrollment in Courses that utilized WBI	.005	.151	2.000	57.000	.860
Group Type * Enrollment in Courses that utilized WBI	.017	.503	2.000	57.000	.608

*p < .05

Finally, results from MANOVA [See Table 48] showed that the main effect for group type [Pillai's Trace = .115, F = 3.710, p < .05] reached a significant difference, while, the main effects for enrollment in courses that utilized WBI [Pillai's Trace = .005, F = .154, p > .05] and their interaction [Pillai's Trace = .013, F = .364, p > .05] failed to reach statistical significance.

Table 48.

MANOVA – Enrollment in Courses that utilized WBI by Group Type – Attitude Change towards Mathematics and Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.115	3.710	2.000	57.000	.031*
Enrollment in Courses that utilized WBI	.005	.154	2.000	57.000	.858
Group Type * Enrollment in Courses that utilized WBI	.013	.364	2.000	57.000	.696

*p < .05

Completion of WBI Courses

To examine the completion of WBI courses instances by group type, a 2 [Completion of WBI courses: yes, no] by 2 [Group type: experimental, control] two-way MANOVA was performed on the combination of achievement, attitude change towards mathematics and computers. Results from MANOVA [See Table 49] showed that the main effects for group type [Pillai's Trace = .230, F = 5.474, p < .01] and their interaction [Pillai's Trace = .135, F = 2.861, p < .05] reached a significant difference, while, the main effect for completion of WBI courses [Pillai's Trace = .016, F = .296, p < .05] failed to reach statistical significance.

Table 49.

MANOVA – Completion of WBI Courses by Group Type – Mathematics Achievement, Attitude Change towards Mathematics and Computers

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.230	5.474	3.000	55.000	.002*
Completion of WBI Courses	.016	.296	3.000	55.000	.828
Group Type * Completion of WBI Courses	.135	2.861	3.000	55.000	.045*

*p < .05

In addition, results from MANOVA [See Table 50] showed that group type [Pillai's Trace = .205, F = 7.475, p = .001] reached a significant difference for mathematics achievement and attitude change toward mathematics, while, the main effects for enrollment in courses that utilized WBI [Pillai's Trace = .006, F = .179, p > .05] and their interaction [Pillai's Trace = .068, F = 2.129, p > .05] failed to reach statistical significance.

Table 50.

MANOVA – Completion of WBI courses by Group Type – Mathematics Achievement and Attitude Change towards Mathematics

Effect	Value	F	Hypothesis df	Error df	Sig.
Group Type	.205	7.475	2.000	58.000	.001*
Completion of WBI Courses	.006	.179	2.000	58.000	.837
Group Type * Completion of WBI Courses	.068	2.129	2.000	58.000	.128

*p < .05

Results from MANOVA [See Table 51] also showed that the main effects for group type [Pillai's Trace = .064, F = 1.907, p > .05], enrollment in courses that utilized

WBI [Pillai's Trace = .014, F = .387, p > .05] and their interaction [Pillai's Trace = .096, F = 2.967, p > .05] failed to reach statistical significance for mathematics achievement and attitude change toward computers.

Table 51.

MANOVA – Completion of WBI Courses by Group Type – Mathematics Achievement and Attitude Change towards Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.064	1.907	2.000	56.000	.158
Completion of WBI Courses	.014	.387	2.000	56.000	.681
Group Type * Completion of WBI Courses	.096	2.967	2.000	56.000	.060

*p < .05

Finally, results from MANOVA [See Table 52] showed that group type [Pillai's Trace = .152, F = 5.005, p = .01] and their interaction [Pillai's Trace = .126, F = 4.032, p < .05] reached significant differences for attitude change toward mathematics and computers, while, the main effects for completion of WBI courses [Pillai's Trace = .016, F = .446, p > .05] failed to reach a statistical significance.

Table 52.

MANOVA – Completion of WBI Courses by Group Type – Attitude Change towards Mathematics and Computers

Effect	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Group Type	.152	5.005	2.000	56.000	.010*
Completion of WBI Courses	.016	.449	2.000	56.000	.641
Group Type * Completion of WBI Courses	.126	4.032	2.000	56.000	.023*

*p < .05

Research Question Two

Is there a relationship between attitudes toward mathematics and mathematics achievement among college students?

To investigate the relationship between attitudes toward mathematics and mathematics achievement, post scores of both variables were analyzed using correlation (regression) analyses. Results from these analyses [See Tables 53 and 54] indicated that a student's attitude towards mathematics cannot significantly be associated with her level of mathematics achievement [t = 1.139, p < .05], and a student's level of mathematics achievement cannot significantly be associated with his attitude towards mathematics [t = 1.139, p > .05].

Table 53.

Correlation Analysis – Post Mathematics Achievement Scores (Predictor Variable) and Post Attitude towards Mathematics (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	2.683	.086		31.192	.000
	Achievement	.051	.045	.142	1.139	.259

*p < .05

Table 54.

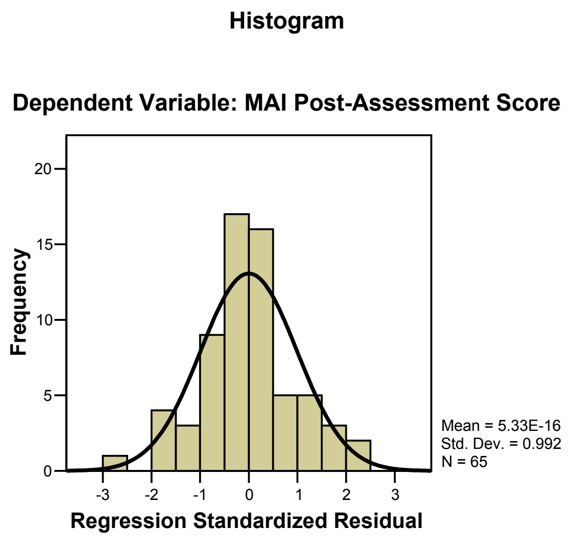
Post Attitude towards Mathematics (Predictor Variable) and Post Mathematics Achievement Scores (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	.296	.963		.307	.760
	Attitude toward Mathematics	.393	.345	.142	1.139	.259

*p < .05

A student can experience high level of mathematics achievement while expressing a negative attitude toward mathematics [See Figure 15] and vice versa [See Figure 16].

(15)



(16)

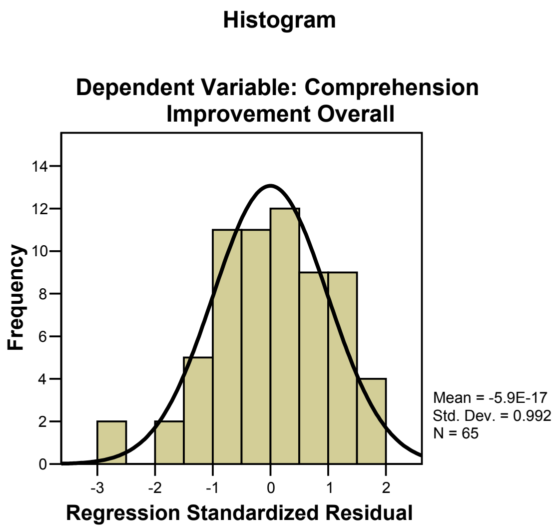


Figure 15. Frequency – Attitudes toward Mathematics (Predictor Variable) and Mathematics Achievement (Criterion Variable).

Figure 16. Frequency – Mathematics Achievement (Predictor Variable) and Attitudes toward Mathematics (Criterion Variable).

Research Question Three

Is there a relationship between attitudes toward mathematics and attitudes toward computers among college students?

To examine the relationship between attitudes toward mathematics and attitudes toward computers, post scores of both variables were analyzed using correlation analyses. Results from this analysis indicated [See Table 55] that a student's attitude towards mathematics can significantly be associated with her attitude towards computers [t = 4.948, p < .05]. That is, if a student experiences a positive attitude toward mathematics, then the student will also experience a positive attitude towards computers [See Figure 17].

Table 55.

Correlation Analysis - Post Attitude towards Computers Scores (Predictor Variable) and Post Attitude towards Mathematics (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	.965	.365		2.643	.010
	Attitude toward Computers	.587	.119	.535	4.948	.000*

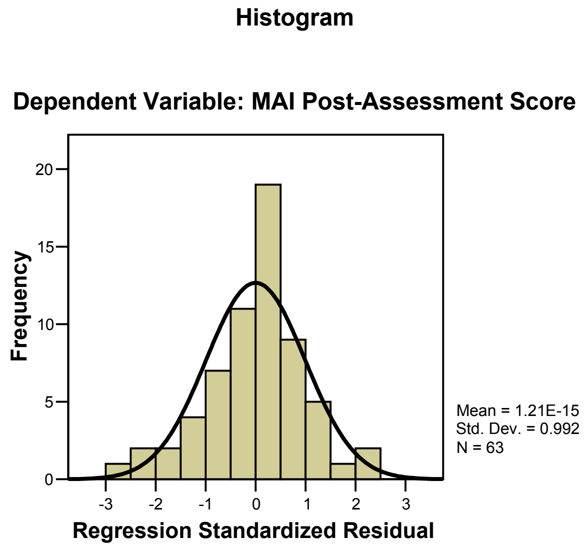


Figure 17. Frequency - Post Attitude towards Computers Scores (Predictor Variable) and Post Attitude towards Mathematics (Criterion Variable).

Furthermore, the results [See Table 56] showed that a student's attitude towards computers can significantly be associated with his attitude towards mathematics [t = 4.948, p < .05]. That is, if a student experiences a negative attitude towards computers, most likely, he will also experience a negative attitude towards mathematics [See Figure 18].

Table 56.

Correlation Analysis - Post Attitude towards Mathematics Scores (Predictor Variable) and Post Attitude towards Computers (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	1.704	.276		6.184	.000
	Attitude towards Mathematics	.488	.099	.535	4.948	.000*

*p < .05

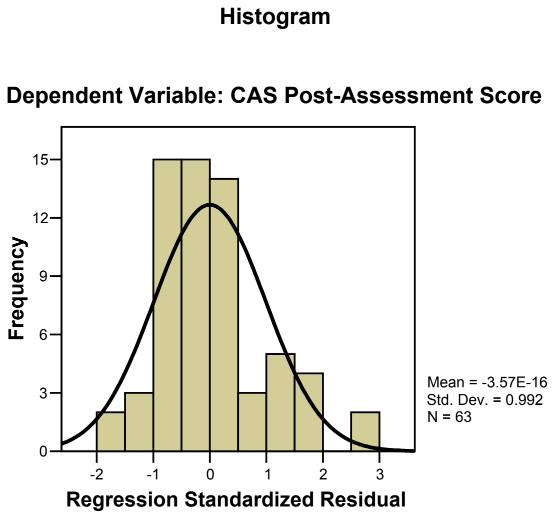


Figure 18. Frequency - Post Attitude towards Mathematics Scores (Predictor Variable) and Post Attitude towards Computers (Criterion Variable)

Research Question Four

Is there a relationship between student satisfaction with WBI and mathematics achievement among college students?

To examine the relationship between student satisfaction with WBI and mathematics achievement, post scores of both variables were analyzed using correlation analyses. Results from these analyses [See Tables 57 and 58] indicated that a student's attitude towards mathematics cannot significantly be associated with her level of mathematics achievement [t = .944, p > .05], and a student's level of mathematics achievement cannot significantly be associated with his attitude towards mathematics [t = .944,

p > .05].

Table 57.

Correlation Analysis - Student Satisfaction with WBI Scores (Predictor Variable) and Post Mathematics Achievement Scores (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	.331	1.343		.246	.807
	Student Satisfaction with WBI	.641	.679	.170	.944	.353

*p < .05

Table 58.

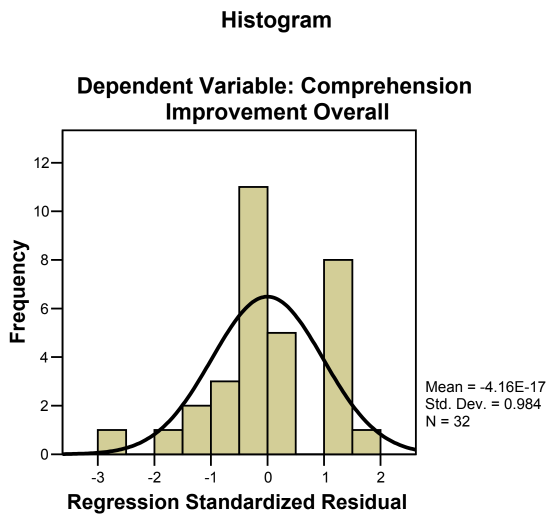
Correlation Analysis - Post Mathematics Achievement Scores (Predictor Variable) and Student Satisfaction with WBI Scores (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	1.874	.098		19.063	.000
	Achievement	.045	.048	.170	.944	.353

*p < .05

A student can experience high level of mathematics achievement while expressing a negative attitude toward mathematics [See Figure 19] and vice versa [See Figure 20].

(19)



(20)

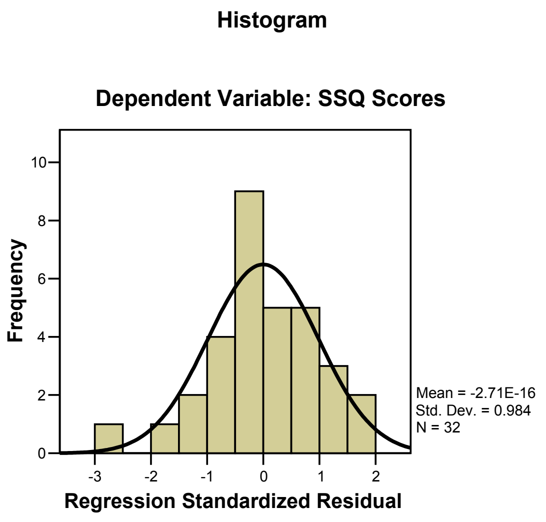


Figure 19. Frequency - Student Satisfaction with WBI Scores (Predictor Variable) and Post Mathematics Achievement Scores (Criterion Variable).

Figure 20. Frequency - Post Mathematics Achievement Scores (Predictor Variable) and Student Satisfaction with WBI Scores (Criterion Variable).

Research Question Five

Is there a relationship between student satisfaction with WBI and attitudes toward mathematics among college students?

To examine the relationship between student satisfaction with WBI and attitudes toward mathematics, post scores of both variables were analyzed using correlation (regression) analysis. Results from this analysis [See Table 59] indicated that a student's satisfaction with WBI can significantly be associated with her attitude towards mathematics [t = 2.266, p < .05]. That is, if a student experiences a high level of satisfaction with WBI, she will also experience a positive attitude towards mathematics [See Figure 21].

Table 59.

Correlation Analysis - Student Satisfaction with WBI Scores (Predictor Variable) and Post Attitudes toward Mathematics Scores (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	1.806	.464		3.894	.001
	Student Satisfaction with WBI	.531	.235	.382	2.266	.031*

*p < .05

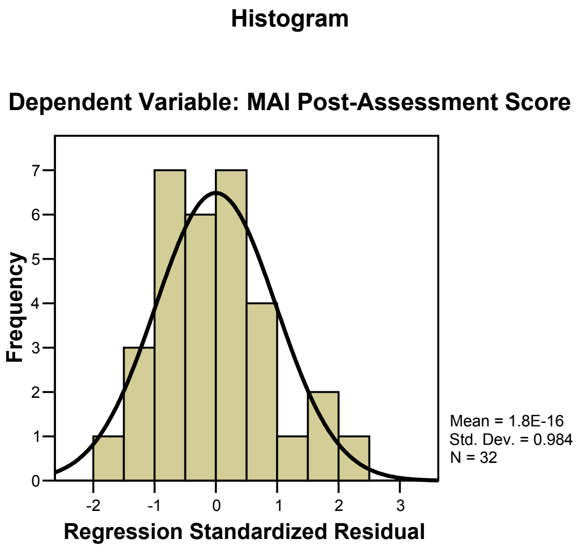


Figure 21. Frequency - Student Satisfaction with WBI Scores (Predictor Variable) and Post Attitudes toward Mathematics Scores (Criterion Variable).

Furthermore, results [See Table 60] showed that a student's attitude towards mathematics can significantly be associated with his satisfaction with WBI [t = 2.266, p <

.05]. That is, if a student experiences a negative attitude towards mathematics, most likely, he will also experience a low level of satisfaction with WBI [See Figure 22].

Table 60.

Correlation Analysis - Post Attitudes toward Mathematics Scores (Predictor Variable) and Student Satisfaction with WBI Scores (Criterion Variable)

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	1.165	.350		3.331	.002
	Attitude toward Mathematics	.275	.121	.382	2.266	.031*

*p < .05

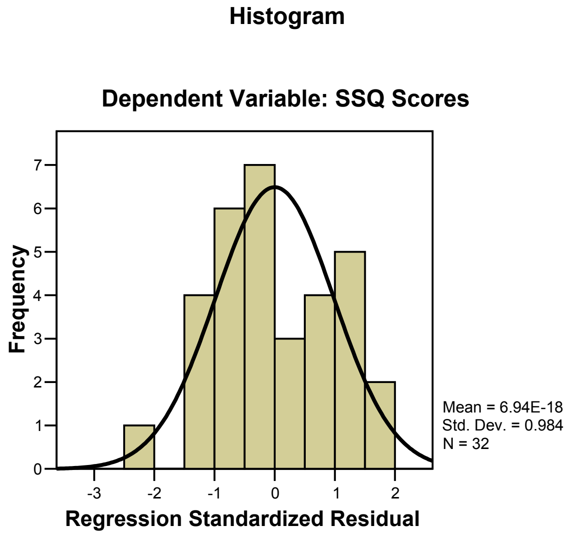


Figure 22. Frequency - Post Attitudes toward Mathematics Scores (Predictor Variable) and Student Satisfaction with WBI Scores (Criterion Variable).

Table 61 presents a summary of all the significant findings discovered by this study.

Table 61.

Summary of All Significant Findings

Dependent Variables	Independent Variables	Reference Table(s)
PE	Group Type	4, 13, 29
AE	Completion_WBI Courses	11, 27
ACTM	Group Type	4, 13, 21, 31
ACTC	Group Type*Completion_WBI Courses	35
PE, ACTM, & ACTC (combined)	Group Type	41, 45, 49
PE & ACTM (combined)	Group Type	42, 46, 50
ACTM & ACTC (combined)	Group Type	44, 48, 52
	Group Type*Completion_WBI Courses	52

Correlation (Variables)	Reference Table(s)
ATM ⇄ ATC	55, 56
SS_WBI ⇄ ATM	59, 60

1. PE = Practice Effect of Mathematics Achievement
2. AE = Application Effect of Mathematics Achievement
3. ACTM = Attitude Change towards Mathematics
4. ACTC = Attitude Change towards Computers
5. SS_WBI = Student Satisfaction with WBI
6. GPF = Graphing Piecewise Functions
7. ATM = Attitude towards Mathematics
8. ATC = Attitude towards Computers

Chapter Summary

This chapter discussed the findings and results of the statistical analyses of data sets for investigating the effects of animated agents with verbal audio in WBI on mathematics achievement, attitudes toward mathematics and computers and student satisfaction with WBI. The analyses revealed significant main effects for animated agents with verbal audio in WBI on the practice effect of mathematics achievement and attitude change towards mathematics. Gender, college classification, and enrollment in courses that utilized WBI proved to be unreliable predictors of mathematics achievement and attitudes toward mathematics and computers for both groups. Finally, the results verified that there exist positive relationships between attitudes toward computers and mathematics and student satisfaction with WBI and attitudes toward mathematics.

CHAPTER V: DISCUSSION AND CONCLUSION

Research questions for this study were developed to add to the body of research concerning WBI in higher education and, particularly, research on the effects of animated agents with verbal audio in mathematics education. These questions especially addressed student mathematics achievement and attitudes toward mathematics and computers. These three areas were investigated through examination of three variables: gender, college classification, and WBI experiences. The following research questions were addressed in this study:

1. Does the presence of animated agents with verbal audio in WBI affect mathematics achievement, attitudes toward mathematics, and attitudes toward computers among college students based on gender, college classification, and WBI experiences?
2. Is there a relationship between attitudes toward mathematics and mathematics achievement among college students?
3. Is there a relationship between attitudes toward mathematics and attitudes toward computers among college students?
4. Is there a relationship between student satisfaction with WBI and mathematics achievement among college students?
5. Is there a relationship between student satisfaction with WBI and attitudes toward mathematics among college students?

Findings

Results of statistical tests conducted determined that there were statistical significances for some relationships, but not all. There was no statistically significant relationship for (1) gender by group type and any dependent variables of mathematics achievement and attitudes toward mathematics and computers, (2) college classification by group type and any dependent variables, and (3) enrollment in courses that utilized WBI by group type and any dependent variables. However, an analysis of results indicated the following:

1. Mathematics achievement, when investigating practice effect, and attitudes toward mathematics improved significantly between the two groups. The experimental group positively changed their attitudes toward mathematics and significantly outperformed the control group.
2. Gender, college classification, and enrollment in courses that utilized WBI proved to be unreliable predictors of mathematics achievement and attitudes toward mathematics and computers between the two groups.
3. Completion of WBI courses proved to be a reliable predictor of mathematics achievement, when investigating application effect.
4. The interaction between the type of group and completion of WBI courses had a significant difference among groups when investigating students' attitudes toward computers. Those in the experimental group that completed WBI course(s) experienced positive attitude change, whereas, those in the control group who completed WBI course(s) experienced a negative attitude change.

5. There was a significant difference between groups on:
    a. the combination of mathematics achievement and attitude towards mathematics and computers,
    b. the combination of mathematics achievement and attitude towards mathematics, and
    c. the combination of attitudes toward mathematics and computers.
6. Attitudes toward mathematics cannot significantly be associated with mathematics achievement and vice versa.
7. Attitudes toward mathematics can significantly be associated with attitudes toward computers and vice versa.
8. Student satisfaction with WBI cannot significantly be associated with student mathematics achievement and vice versa.
9. Student satisfaction with WBI, however, can significantly be associated with student attitudes toward mathematics.

Discussion

This section will discuss findings and results regarding the five research questions. Within this section, the following points will be discussed:

- The effect of animated agents with verbal audio in WBI on mathematics achievement, attitudes toward mathematics, and attitudes toward computers based on gender, college classification, and WBI experiences;

- An examination of relationships between mathematics achievement, attitude towards mathematics, attitudes toward computers, and student satisfaction with WBI.

Animated Agents with Verbal Audio in WBI

The WBI tutorial, known as *Adam*, used in this study incorporated animated agents with verbal audio. Unlike many other animated agents (e.g., Herman the Bug (Lester, Stone, Converse, Kahler, & Barlow, 1997)) in educational technology, the facial-only represented animated agents implemented in the tool were static and exhibited verbal redundancy, meaning that they spoke the identical words that were printed on the screen. Verbal redundancy has been proved to be successful with learning (Moreno & Mayer, 2002). Moreno and Mayer (2002) showed that verbal redundancy in CBI can improve student performance without causing cognitive overload. Cognitive overload can occur if WBI designers and developers incorporate too many redundant features in WBI (redundancy effect) (Mayer, Heiser, & Lonn, 2001)

The animated agents in *Adam* also did not demonstrate deictic believability which is very essential when using animated agents in a cognitive learning environment (Doyle, 2002; Lester & Stone, 1997). Animated agents can exhibit “deictic believability” by replicating the way humans refer to objects in their environment through the combination of locomotion, speech, and gestures, in a virtual environment and providing real-time advice to students. Providing immediate feedback and/or help to students while completing a lesson is needed for meaningful learning (Lester & Stone, 1997). Lester and Stone (1997) proved that students are favorable to learning from an animated agent if it looks and acts “believable”.

Contrary to Gilbert (2002), this tool does not offer adaptive instruction. Adaptive instruction occurs when an instruction adapts to a student’s learning style while in progress of learning (Song & Keller, 1999). In order for a tool to adapt to a student’s learning style, it must “learn” the student’s learning style (maybe, through a completion of a learning style inventory). *Adam* does not adapt to students’ learning needs, based on individual learning styles data collected before using the tool nor does it have the capability to recognize a particular learning style or difficulties with a concept while a student is using the tool. However, this tool does offer a many-to-one instructional method, which provides several different methods for presenting instructional information pertaining to one subject. The current capabilities of *Adam* resemble a drill-and-practice tool, which leads to the practice effect and positive reinforcement of the lesson material. Thus, this tool should be only used as a supplementary tool along with classroom instruction.

As hypothesized in this study, the use of animated agents with verbal audio in WBI positively affected mathematics achievement among college students (Atkinson, 2002; Baylor, Ryu, & Shen, 2003; Craig, Gholson, & Driscoll, 2002; Moreno, 2001) when investigating the practice effect, but not the application effect. Contrary to Moreno, Mayer, Spires, and Lester (2001), students who completed mathematics lesson modules with the presence of animated agents with verbal audio experienced an increase in mathematics achievement and felt more motivated to learn the lessons. This finding is supported by the information delivery hypothesis, an implication of Mayer's cognitive theory of multimedia theory (Mayer et al., 2001) and empirical studies on verbal redundancy (Moreno & Mayer, 2002). The information delivery hypothesis states "students learn more when the same information is delivered by means of more paths rather than fewer paths" (p. 190). Thus, exposing students to learning material that is delivered in two methods – narration and on-screen text – is better than exposing them to one method – on-screen text.

In this study, verbal redundancy improved learning because it allowed the students to mentally choose what modality that best suited their learning styles (Moreno & Mayer, 2002). This finding is also supported by several research studies summarized in Chapter 2 (Baylor, 2002; Baylor et al., 2003; Brewer, Qi, & Gilbert, 2002; Dehn & van Mulken, 2000; Johnson, Rickel, & Lester, 2000; Merrill, 2003) and contributes to the research of animated agents with verbal audio in mathematics education.

In particularly, the students in the experimental group demonstrated the practice effect, but not the application effect. They performed well on the lesson assessments which were administered shortly before and after the introduction of the lesson module, but the exams scores did not reflect a significant difference between the experimental and control group. The experimental group might have demonstrated intense short-term practice, instead of sustained long-term practice (Willington, 2004). According to Willington (2004), intense short-term practice is a brief review of material, whereas, sustained long-term practice represents "[an] ongoing review or use of the target material (e.g., regularly using new calculating skills to solve increasingly more complex math problems… and taking regular quizzes or tests that draw on material learned earlier in the year)." (p. 1). To achieve the application effect, a student must engage in sustained long-term practice[14]. The study did not allow for a long-term practice because data related to application effect was collected after a couple of days rather than several weeks. This may have contributed to the findings of no application effect.

When investigating the application effect, completion of WBI courses was a reliable predictor. Students who did not completed a WBI course outperformed the students who did. An explanation for this finding might be that the majority of the students in this study did not complete one WBI course and performed well on the exams.

In this study, the presence of animated agents with verbal audio in web-based mathematics education and positive reinforcement might have led to the improvement of students' attitudes toward mathematics. 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 motivation in mathematics whereas the students in the control group experienced negative changes in all six areas. Because the students in this study were non-STEM majors, it would seem that WBI in mathematics education can help attract under-represented groups to the discipline.

Furthermore, this finding coincides with Baylor, Ryu, and Shen's (2003) study. They concluded that animated agents with verbal audio can encourage and motivate students to learn which influence their attitudes toward learning. Thus, students who

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[14] In this study, sustained long-term practice is equivalent to the application effect.

used instructional materials that incorporated animated agents with verbal audio in a web-based learning environment to learn mathematics will express a more positive attitude towards mathematics and learning mathematics than those who do not.

When investigating attitude change toward computers, there was no significant difference among the two groups. Both groups experienced a negative attitude change towards computers. They both felt more anxious about using computers and less confident about computers in education and expressed a dislike towards computers. However, the experimental group experienced a slightly more negative change than the control group. Students in the experimental group might have experienced this negative change because *Adam* may not have met their expectations, especially for those students with WBI experience. Because *Adam* is more of a drill-and-practice tool rather than assisted or adaptive instruction that can adjust to different performances, the students may have become bored with using the tool. This finding contradicts Liu and Reed's (1995) study which proved that CAI significantly increased student performance and decreased computer anxiety.

Additionally, this study found a significant difference among the interaction between the independent variables, group type and previous completion of WBI courses, for attitudes toward computers. Students in the experimental group, who have completed a WBI course, had a positive attitude change, whereas, students with the same experience in the control group had a negative attitude change. It seems that completion of a course that utilized WBI provided some level of expectations for the type of instructional activities. Meaning, WBI allows the student to interact with the information and provides immediate feedback and some level of animation which can grab the student's attention. The control group only interacted with a paper-based version of the instruction, which does not hold the same characteristics of WBI. If WBI meets the basic expectations, then one might assume that students will sustain or improve their attitudes. However, those who do not interact with WBI, may be disappointed and less interested with the paper-based version, and rely on previous or current computer experiences in other courses when describing their attitudes. When WBI is designed effectively, students can become motivated to learn and feel more comfortable about using computers to learn. These findings coincide with many research studies that were summarized in Chapter 2 (Czaja & Sharit, 1998; Pancer, George, & Gebotys, 1992; Schumacher, Morahan-Martin, & Olinsky, 1993; Walters & Necessary, 1996).

Finally, there were significant differences among groups for the combination of achievement and attitude towards mathematics and computers; the combination of mathematics achievement and attitude towards mathematics; and the combination of attitudes toward mathematics and computers. This statement is true because as discussed earlier there were significant differences among the two groups for mathematics achievement and attitudes toward mathematics. Thus, according to this study, the presence of animated agents with verbal audio in web-based mathematics education can significantly improve mathematics achievement and attitudes toward mathematics, but not attitude change towards computers (Bahr & Rieth, 1989; DeVaney, 1996; Wenglinsky, 1998).

Mathematics Achievement, Attitudes toward Mathematics, Attitudes toward Computers, and Student Satisfaction with WBI

Attitudes toward mathematics can significantly be associated with attitudes toward computers, but not mathematics achievement and vice versa. A student who expresses a positive attitude toward mathematics will most likely express a positive attitude toward computers. However, this same student may still perform poorly on mathematics assessments. Reasons for this may be the delivery of instruction, the instructor's teaching styles, and the degree of difficulty of the instruction. Mathematics is a subject disliked by most students in this sample based on data collected for this study.

Student satisfaction with WBI can significantly be associated with student's attitude toward mathematics, but not their mathematics achievement, according to this study. After completing WBI lesson modules that delivered mathematical materials and tasks, students' attitudes toward mathematics changed positively. The presence of the animated agents with verbal audio in the lesson modules might have contributed to this fact. However, even though students were satisfied with learning mathematics through WBI, their mathematics achievement did not significantly increase.

Limitations

Initial plans for the study included an entire semester for students to participate. This would have allowed for a more adequate examination of the application effect for mathematics achievement because the students would have had more time to practice different concepts before encountering a related math problem. However, students would typically discontinue participation after the second or third lesson module. The relatively small number of participants and length of involvement may be due to the lack of monetary compensation and the time outside of class to go to a computer lab in order to use *Adam*. In addition, the participants for this study represent a sample of convenience. These issues affect the generalizability of the study to the general population of non-math majors.

Furthermore, the lesson module assessments for the pretest and posttest were exactly the same. Because of the short-time span between the tests, it was possible that some students may have remembered problems and answers when completing the posttest. As a result, this limitation may affect the validity of the positive practice effect for the experimental group. This issue could be eliminated by having similar problems on the posttest that assess the same concepts and skills.

Implications

This section will discuss a few implications for designers and developers of WBI courses and instructors in mathematics educations.

For designers and developers of WBI

From this study, designers and developers of WBI in postsecondary education can see that by incorporating animated agents with verbal audio in web-based mathematics education, mathematics achievement and attitudes toward mathematics can improve significantly. The presence of animated agents with verbal audio can also motivate students to learn, gain and keep their attention, and help their focus on learning, which yields to great success.

The characteristics, such as gender, and functions of the animated agents are important to consider when designing and developing a WBI virtual learning environment, according to this study. Designing animated agents with verbal audio that students can relate to is crucial to their learning (Baylor, 2002). Thus, the designer and developer should keep in mind their audience and the tool that the audience will be using to access the learning environment when designing and developing a web-based instructional system that implements animated agents with verbal audio.

Furthermore, designers should develop agents that reflect the nature of relationships between people. The animated agents resemble people in a virtual environment; thus, when confronted by an animated agent, people might view that agent as a real person.

For instructors

As indicated in this study, using a supplementary tool, particularly, a web-based tutorial, in mathematics courses can improve achievement and attitudes in mathematics education. In addition to their lectures, instructors in mathematics education can make available a web-based tutorial that is accessible at all times. This way, if a student needs assistance and the instructor is unavailable, he can log on to the tutorial and view the material again and assess his learning of the material as many times as he wants and at any time.

In addition, the use of a web-based tutorial in a course can also motivate and encourage students to learn. Not only is WBI convenient, it offers many resources via the Web that can better a student's learning experience.

Future Research

This study investigated the effects of animated agents with verbal audio on mathematics achievement and attitudes toward mathematics and computers with a small sample size that was chosen based on convenience. It is highly recommended that a mixed methodology – longitudinal study be conducted to examine fully the effect of animated agents with verbal audio in mathematics education. This study can prove how much and how long students retain information learned from the presence of animated agents with verbal audio.

Another recommendation for future research is to conduct the same study in a different subject matter. For example, one can verify if the presence of animated agents with verbal audio in a learning environment can improve a student's understanding in a chemistry or physics course, in addition to attitude towards learning chemistry or physics.

To improve generalizability, the same study should be conducted using a large sample size that is not chosen based on convenience. This method will decrease the occurrence of bias results.

A study investigating four different implementations of *Adam*: agent-only, audio-only, both agent and audio, and no-agent-no-audio, could improve the validity of these results. This study could verify if WBI alone can contribute to change in achievement and attitude change.

Another variation for understanding the impact of animated agents is to examine the effects of animated agents on achievement among participants who can choose their agents compared to those who cannot and the effect of inherent characteristics of animated agents on application effect. This will show if personal choice of an agent and an agent's inherent characteristics will affect achievement.

Finally, a web-based instructional system that incorporated conversational agents, whose voices are more human-like, would be another variation for future research. In this conversational system, the agents would behave more like "real" people by asking questions when the student needs help or has made incorrect choices. Mathematics achievement and attitudes might improve significantly.

Conclusion

According to this study, the presence of animated agents with verbal audio in CBI has encouraged improvement in learning and attitudes. Students who learn with the assistance of animated agents with verbal audio are more likely to comprehend learning materials better and experience higher levels of motivation toward learning than those students who did not (Johnson et al., 2000). This form of instruction can be beneficial to students who are experiencing some difficulties with a subject matter, particularly mathematics education.

Mathematics is a subject matter that is disliked by many students. Students develop attitudes towards mathematics based on teachers' and parents' attitudes toward mathematics (Aiken, 1972). If a students have a negative attitude toward mathematics, they will not perform well in mathematics courses (Aiken & Dreger, 1961). Thus, it is important to educators to find a way to make students feel comfortable in a mathematical learning environment. Based on this study, the presence of animated agents with verbal audio in a mathematical learning environment can make a student feel more comfortable and motivated to learn which leads to improvement in mathematics achievement and attitudes (Baylor & Kim, 2003).

Moreover, attitudes toward mathematics and attitudes toward computers can significantly be associated with each other. Thus, if a student feels good about using the computer to learn, then mathematics instructors should consider incorporating computers in their courses. Finally, student satisfaction with WBI can significantly be associated with attitudes toward mathematics. After completing web-based math lesson modules, students had a more positive attitude towards mathematics. Thus, based on these findings, using WBI that incorporates animated agents with verbal audio can be beneficial to mathematics education.

APPENDIX A: ADAM

Excerpt from Gilbert (2002)

Abstract

The acceptance of animation technologies into our culture is growing within the up coming generations. Video games such as Sony PlayStation (SONY PlayStation North America, 2002) have become part of the culture for young people from kindergarten through undergraduate school. Animation technologies have been implemented into educational systems in the form of animated pedagogical agents (Johnson et al., 2000). The research described here aims to take advantage of this wide spread acceptance of animation technologies by introducing animated pedagogical agents as teachers in an adaptive instruction environment called Adam.

Introduction

Gilbert (1999)discussed the implementation of an adaptive instruction system called Arthur. In this paper, Gilbert introduced the Many-to-One (M-1) instructional model. The M-1 instructional model refers to the relationship between educators and learners. In this model, there are many educators per learner. In order to fully understand this model, some terminology must be introduced. In this paper, courses are composed of many lessons. As an example, on a typical syllabus, there are many lessons listed that will be discussed through out the course. Lessons can be further divided into one or more concepts. Concepts are the smallest unit of instruction. These concepts are called instructional units through out this paper.

An instructional unit has two subsections, instruction and assessment. In other words, each instructional unit has instruction, which is followed by an assessment for that instruction. Figure 1 gives an illustration of the M-1 instructional model. In figure 1, there are three educators, Lopez, Brown and Smith that teach the same course. This course has five instructional units. The rows represent a single course that is taught by the educator on the left. Therefore, figure [23] contains three implementations of the same course taught by three different educators. Each educator uses his or her own pedagogical methods to deliver instruction. The columns in figure 1 represent instructional units. Each instructional unit consists of instruction and an assessment created by the instructor at the top of the column. This implementation is how the M-1 instructional model begins. Another way to conceptualize the M-1 instructional model is to imagine a single learner in a classroom full of educators that teach the same subject, but each educator teaches the subject using a different pedagogical approach. In the physical implementation, the M-1 instructional model is not feasible. Using technology, such as the internet, it is possible to implement a representation of the M-1 instructional model. This implementation will be called Adam.

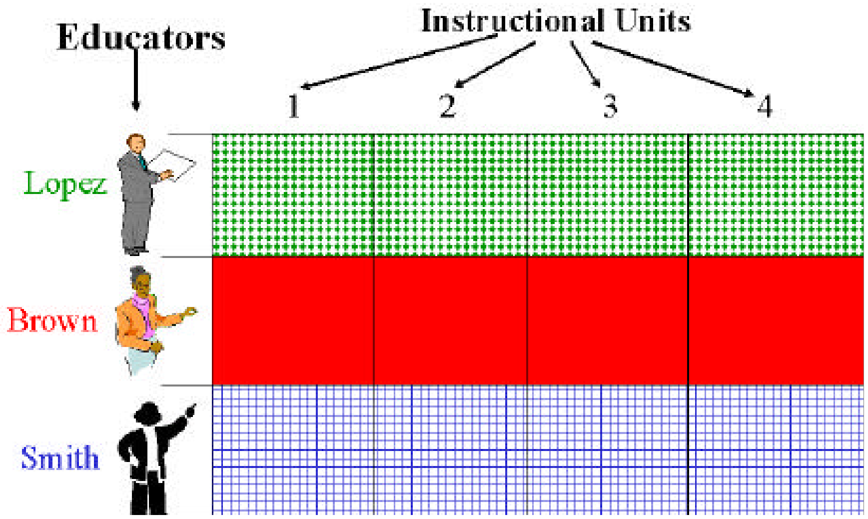

Figure 23. Many-to-One Instructional Model.
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Architecture

The physical architecture of the Adam environment begins with a web server and an instruction repository. This web server is the agent server. The agent server will host all of the instructional units that were described in the previous section. The instructional units are stored in an instruction repository. Each instructional unit is maintained as a web deliverable, instructional screenplay. The instructional screenplays will be discussed in further detail in the instruction creation section below. Instructional data such as the instructional unit's name, description, author's contact information, etc. will be stored in the repository for each instructional unit. This data comes alive when it is accessed by one of the delivery systems.

Delivery Systems

Delivery systems can exist on different web servers or they can reside on the agent server. Delivery systems select instructional units from the instruction repository. This process is called instruction method selection, which is discussed in further detail in the instruction delivery section. Recall that each instructional unit is composed of instruction and assessment.

The instruction has been created by an educator using his or her own pedagogical style(s). When a learner uses Adam, the learner will be assigned an instructional unit from the instruction repository. The process of selecting an instructional unit, instruction method selection, occurs inside of the delivery systems. Figure [24] gives an illustration of how delivery systems interact with the agent server and the learners. Notice that there can be more than one delivery system.

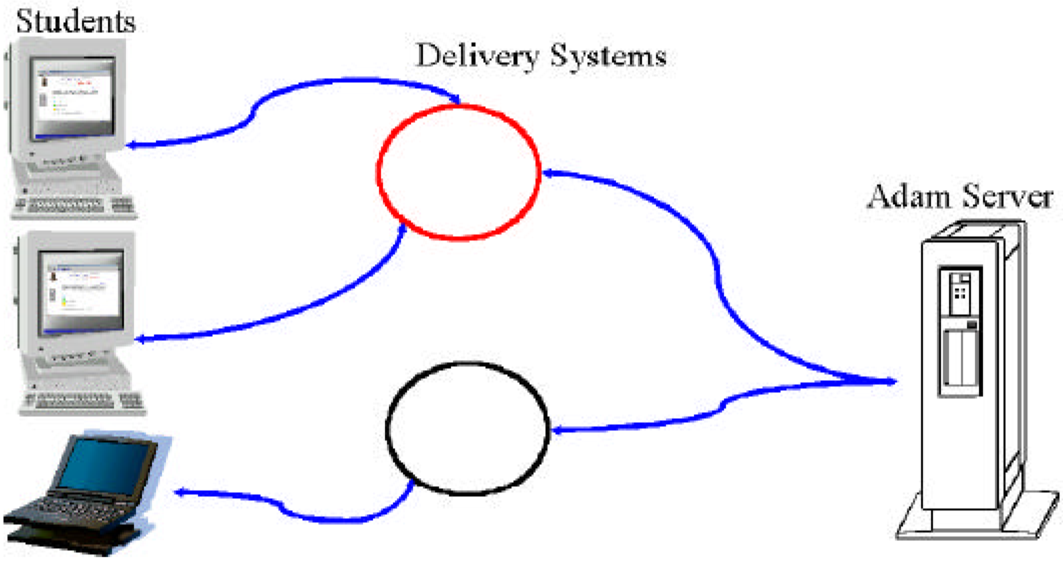

Figure 24. Adam Architecture.
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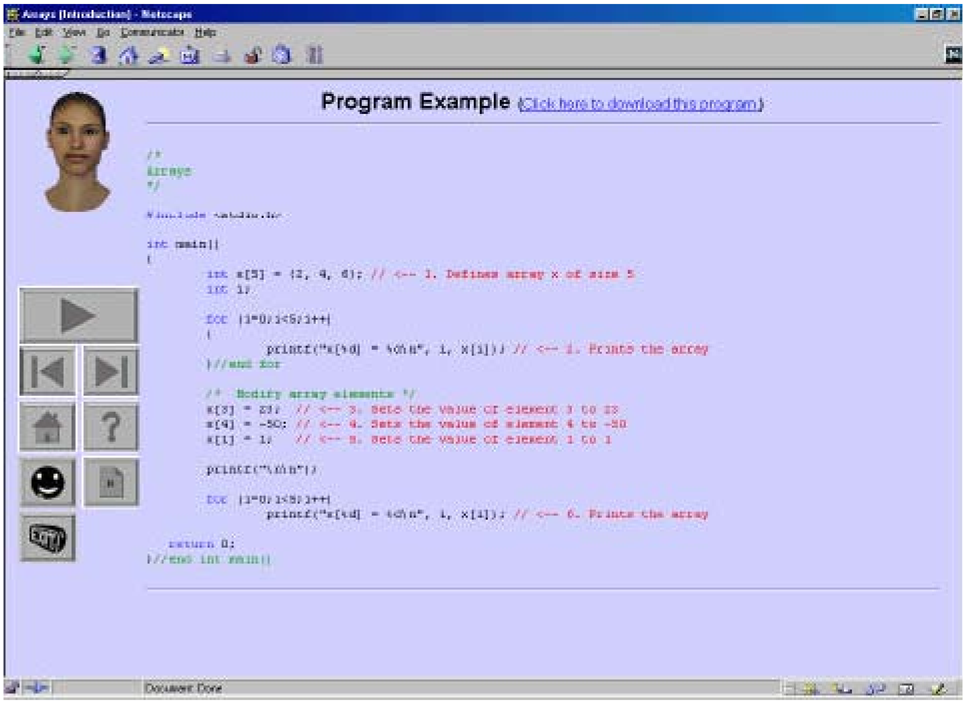
This is due to the fact that instruction method selection may vary. For example, in figure 1 the instructional units are numbered 1 through 4. The sequence for selecting these units may be 1, 2, 3 and 4 for a specific delivery system. For another delivery system, the sequence may be 2, 1, 3 and 4. This is an example of curriculum sequencing, which is the order in which instructional units are selected. Curriculum sequencing is just one variable that distinguishes delivery systems. The other variables will be discussed in the instruction delivery section. The server side of Adam has been discussed in this section and the user interface or client side follows.

User Interface

The user interface can be divided into two sections, navigation and content. Figure [25] has an illustration of the user interface layout. On the right hand side of the user interface there is a navigation frame. The navigation frame consists of a control panel and an animated pedagogical agent (Johnson et al., 2000). The control panel allows the learner to start and stop a session, submit a question, logout, change the teacher's persona and to review previously seen instructional units. When the learner starts a session, the agent will begin to deliver instruction by speaking and manipulating web pages and/or objects in the content frame. The content frame is where all manipulatives used during instruction will appear. The agents used in this environment are implemented in the form of a web browser plug-in. This plug-in was developed by Haptek (2002). The Haptek plug-in is downloadable and works on windows based machines. The plug-in performs text to speech in English and Spanish. It also provides voice manipulation and face animation. The face animation controls allow the developer to manipulate the agent's emotions in real time. The agent plays the role of educator in an elaborate educational screenplay.



Program Example (Click here to download this program)

```
/*
Arrays
*/

#include <stdio.h>

int main()
{
        int x[5] = {2, 4, 6}; // <-- 1. Defines array x of size 5
        int i;

        for (i=0;i<5;i++)
        {
                printf("x[%d] = %d\n", i, x[i]); // <-- 2. Prints the array
        }//end for

        /*  Modify array elements */
        x[3] = 23;  // <-- 3. Sets the value of element 3 to 23
        x[4] = -50; // <-- 4. Sets the value of element 4 to -50
        x[1] = 1;   // <-- 5. Sets the value of element 1 to 1

        printf("\n\n");

        for (i=0;i<5;i++)
                printf("x[%d] = %d\n", i, x[i]); // <-- 6. Prints the array

   return 0;
}//end int main()
```

Figure 25. User Interface Layout.
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Instruction Creation

Before learners can use Adam, instruction must be created and implemented into Adam's architecture. The process of instruction creation is very tedious in its current state. The output of the instruction creation process is an educational screenplay that stars animated pedagogical agents. The process begins with real educators. In the current implementation, educators are video taped in a tutoring environment. The materials and all other manipulatives used during the tutoring session are collected when the session ends. Each session is focused on a specific concept. Recall, that concepts are later transformed into instructional units. The educators are also asked to create an assessment in the form of a quiz for each session. The goal of the assessment is to determine if the learner understood the concept(s). This process will be executed for a number of concepts with different educators. Once all of the concepts and assessments have been collected, the conceptual level of a Many-to-One instructional model can be implemented. In figure [23], there are three educators and four instructional units. Those instructional units would have been captured on video tape and the assessments created by each educator for those concepts will be collected as well. After all the concepts have been video taped from each educator and all the assessments have been collected, the instructional units will be created in the form of screenplays.

Creating Screenplays

The video tape of the tutoring sessions will be used to extract the educator's words as a digital audio file, .wav format. The .wav files of the educator's instruction will be transformed into compressed digital audio files that contain face animation information using Haptek's People Putty product. The output of this process is an .ogg file. In addition, each manipulative, that the educators used, will be transformed into a web deliverable format (i.e. html, video, Java, or Flash). For example, everything that an educator writes or manipulates during the tutoring session will be transformed into a web compliant format. Next, the .ogg files and all the web deliverable materials will be placed along a conceptual timeline. This timeline is a reenactment of the tutoring session minus the physical presence of the educator and the learner. For example, an educator begins the tutoring session with a verbal introduction of a concept. This introduction may last 20 seconds. At that time, the educators write a couple of sentences on a piece of paper or a chalk board. These actions would be replicated along the conceptual timeline. Once the audio and materials have been conceptually synchronized, the educational screenplay will be stored in the instruction repository.

Storing Screenplays

The educational screenplays are stored in the instruction repository as instructional units. Recall, that instructional units are composed of instruction and assessment. From each tutoring session with a real educator, instruction is captured in the form of digital audio and web deliverable materials along a conceptual timeline. The assessments are also collected and converted into a web deliverable quiz. The instruction repository houses the digital audio .ogg files, web deliverable materials and the conceptual ordering of the two together. The location or web address of the web deliverable materials is stored in the database on the agent server. This allows each web deliverable manipulative to be accessed via its web address, or URL. This instruction creation process is very time consuming and labor intensive. In an effort to automate this process, an authoring tool is being developed.

Instruction Delivery

After the instructional units have been created and stored as screenplays with assessments, learners will be given access to them. When a learner uses Adam, the first task presented to the learner will be the educator selection screen. Figure [26] has a sample educator selection screen.

In figure 4, there are six different animated agents that can play the role of educator. Each agent has a different persona. Each agent has a unique persona that separates it from the others. Personas can differ in appearance and facial expression. Educator selection is similar to persona selection seen in popular video games such as Sony PlayStation (2002). In the video games, each player selects a team or person to represent him/her in the game. In Adam, the learner selects a teacher to provide instruction. The instruction behind the agent is stored on the agent server in the form of instructional units. Once the learner selects an agent educator, an instruction unit will be selected from the instruction repository.

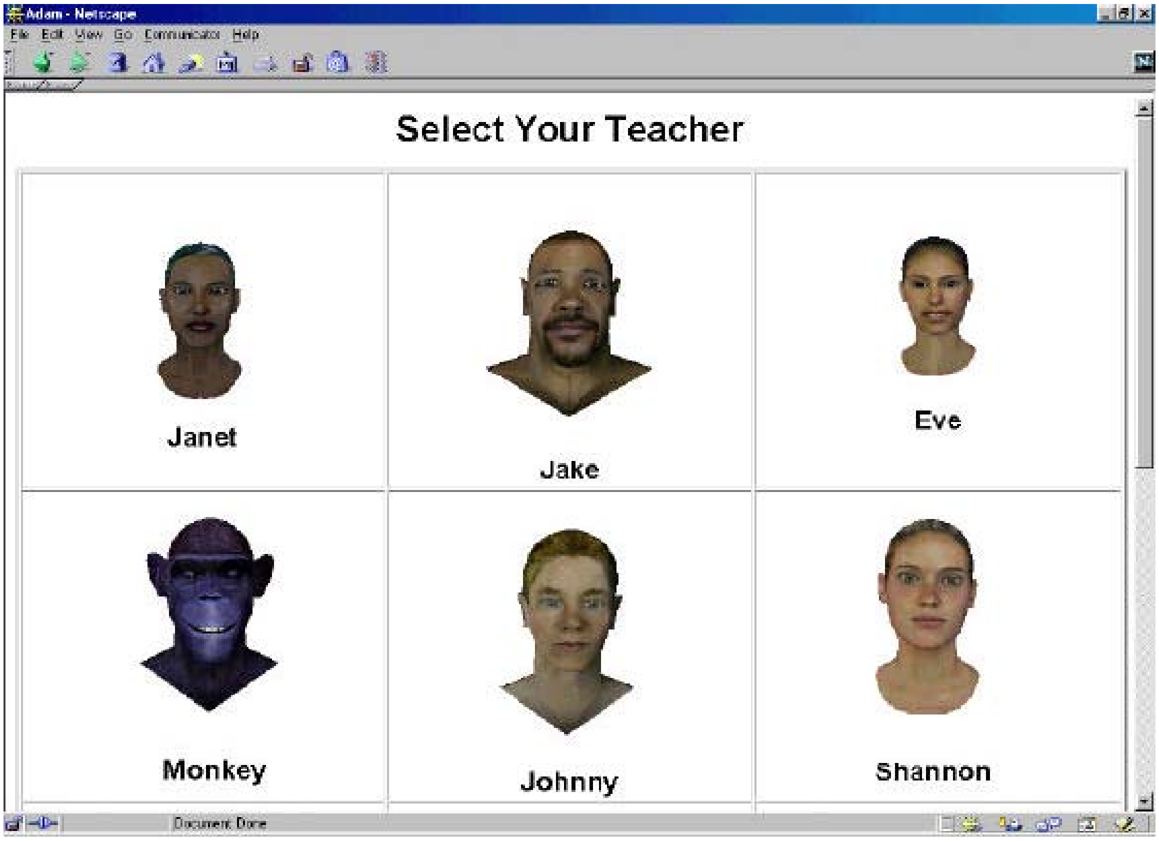

Figure 26. Educator Selection.
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Instruction Method Selection

The process of selecting an instructional unit from the instruction repository is called instruction method selection. Instruction method selection occurs at two distinct points within Adam, entry and after assessment. The first is the point of entry. When the learner selects an agent teacher, instruction method selection must occur.

For example, learner Kristian logs into Adam. When Kristian enters Adam, a delivery system will be assigned to his course. Next, Kristian is presented with the educator selection screen in figure [26]. He selects the first agent, Jake, along the bottom row to be his teacher. The system will refer to the instruction repository and select instructional unit number 1 from figure [23]. Because Kristian is new to Adam, the first instructional unit will be selected at random. Notice that in figure [23], there are three different instructional unit number 1s. Assume Ms. Boykin's, the teacher in the middle, instructional unit 1 was selected. After the instructional unit has been selected, the interface will change and Kristian will be presented with the interface seen in figure [25] with Jake as the teacher.

When Kristian presses the Play button on the control panel, Jake will begin to speak the transcribed text recorded from Ms. Boykin's tutoring session. The content in the right frame, figure [25], will change and display the web deliverable versions of Ms. Boykin's materials. This is the educational screenplay of instructional unit number 1 modeled after Ms. Boykin's tutoring session taught by Jake. Upon completion of instructional unit number 1, Kristian will be given the assessment created by Ms. Boykin for instructional unit number 1. After Kristian completes the assessment quiz, instruction method selection will occur again.

The completion of each instructional unit is marked by an assessment quiz. If the learner performs well on the assessment quiz, then the learner is presented with the next logical instructional unit using the same educator. For example, if Kristian performs well on the assessment quiz for instructional unit number 1, then he will be presented with instructional unit number 2, the next logical instructional unit, created by Ms. Boykin. In general, performing well is observed when the learner scores above a certain threshold. This threshold can be called the performance threshold. This may vary across delivery systems. For example, Gilbert (2000)used a performance threshold of eighty percent for his studies. In other words, the learners had to score eighty percent or higher on their assessments before they could move onto the next logical instructional unit. Eighty percent was selected based upon mastery learning theory (Bloom, 1976), where an eighty percent score determines mastery of a subject. Other delivery systems may set the performance threshold higher, i.e. ninety percent, or lower, i.e. seventy percent. In either case, the performance threshold must be met or exceeded before the learner can proceed onto the next logical instructional unit. If the learner scores below the performance threshold, then the learner will receive corrective instruction, which requires instruction method selection. Corrective instruction can be viewed as instruction that covers the same concept, but it is explained a different way. Therefore, the same subject is taught using a different instruction method. This process of providing corrective instruction when the learner falls below the performance threshold is called adaptive instruction.

Adaptive Instruction

Adaptive instruction refers to the process of adapting the instruction method in order to provide the learner with a personalized instructional experience. In some cases, adaptive instruction aims to accommodate learning style (Dunn & Dunn, 1978). In either case, adaptive instruction requires that an instruction method will be selected from a pool of varying instruction methods as seen in figure [23]. Gilbert (2000) used a form of case-based reasoning to provide adaptive instruction in his studies.

Each assessment quiz was defined as a case in those studies. All the cases consisted of similar attributes such as title, number of questions, number of questions answered correctly, etc. When a learner performed poorly on an assessment, the learner's assessment quiz would be transformed into a case. This case would be compared to previous learner cases. If a previous learner has performed in a similar manner as the current learner on the same assessment quiz, then the system would assign the current learner an instruction method based upon the previous learner's experience. This concept is based upon the premise that learners that perform similarly on the same assessments may have similar learning styles. Therefore, establishing assessment quizzes as cases affords the ability to compare learners' assessments. For example, assume Kristian scored a seventy percent on the assessment quiz for instructional unit number 1 where the performance threshold was set to eighty percent. This quiz consisted of ten question and Kristian missed questions 5, 9 and 10. Also, assume a previous learner, Deborah, scored seventy percent on the same quiz, but she missed questions 5, 8 and 9. In the database, there is a case for Deborah and Kristian. Deborah's case contains information that shows she later passed instructional unit number 1 using Mr. Gabriel's instructional unit. Therefore, the system would assign Kristian Mr. Gabriel's instructional unit number 1 because Kristian and Deborah's assessment cases are closely matched and Mr. Gabriel's instructional unit number 1 worked well for Deborah. Adaptive instruction can occur throughout the learner's travel through Adam. An end result once the learner completes a course will be a learner map. The learner map represents all of the various instructional units selected by Adam. It is possible to compare learner maps at the end of the course in order to identify similarities between learners.

Conclusions

With the acceptance and integration of animation technologies into society, Adam has the opportunity to make a significant impact in providing universal access to alternative forms of instruction. As technology integrates further into the common household, tools such as Adam will give access to instruction from educators that would normally be out of reach.

Adam has the ability to provide culturally responsive instruction to learners where their culture is not represented. For example, rural communities will be given access to instruction created by educators from across the globe. The demographic limitations of instruction are broken down by Adam.

Adam is part of an extensive research study that is supported by the National Science Foundation (Grant #EIA-0085952). Adam's instruction repository is currently being populated with instruction. The first prototype of Adam has been tested using introductory level computer science programming. On the instruction creation side, an authoring tool is being developed that will allow educators to create educational screenplays online. This tool is called Eve. The tool features an animated pedagogical agent that plays the role of instructional designer. The agent assists educators during the creation of their instructional units as screenplays. Educators record their voice for instruction, which will be spoken during the screenplay. The educators also have the ability to type in text that will be displayed on the screen and upload other web deliverable objects, i.e.: images. All of their materials are stored on the agent server. The agent instructional designer guides the educators through this process.

APPENDIX B: COMPUTER ATTITUDES SCALE

SURVEY OF ATTITUDES TOWARD LEARNING ABOUT AND WORKING WITH COMPUTERS

Brenda H. Loyd and Clarice P. Gressard
University of Virginia

The purpose of this survey is to gather information concerning people's attitudes toward learning about and working with computers. It should take about fifteen minutes to complete this survey. All responses are kept confidential. Please return the survey to your instructor when you are finished.

Please check the blank, which applies to you.

Demographic Factors

1. Age: ___________

2. Race/Ethnicity: ☐ African American ☐ American Indian or Alaskan Native
☐ Asian or Pacific Islander ☐ Caucasian American
☐ Hispanic ☐ Non alien resident
☐ Unknown ☐ Other: _________________

3. College Classification: ☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior

4. Major area of study: ☐ Literal Arts ☐ Business ☐ Nursing ☐ Sciences
☐ Mathematics ☐ Engineering ☐ Education
☐ Undeclared ☐ Other ______________________________

5. Gender: ☐ Male ☐ Female

Computer Technology

6. Experience with learning about or working with computers:
☐ 1 week or fewer ☐ 1 week to 1 month ☐ 1 month to 6 months
☐ 6 months to 1 year ☐ 1 year or 2 years ☐ 2 years or more

7. Computer knowledge classification: ☐ Novice ☐ Intermediate ☐ Advanced ☐ Expert

8. Do you own a home computer? ☐ Yes ☐ No

Internet & the World Wide Web (Web)

9. Do you have Internet access? ☐ Yes ☐ No

10. You primarily search the Web: ☐ at home ☐ at school ☐ at work
☐ at the library ☐ Other: ___________________

11. Have you ever enrolled in a course that utilized Web-based instruction? ☐ Yes ☐ No

12. If you answered "*Yes*" to Question #11, indicated number of courses that utilized web-based instruction: _____
If "*No*", skip to skip Question #13.

13. Have you ever completed a 100% Web-based course that did not meet in a face-to-face environment?
☐ Yes ☐ No

14. If you answered "Yes" to Question #13, indicated number of courses: _____
If "No", skip to skip Question #15

15. Daily, how often do you search the Web? ☐ Rarely ☐ Occasionally ☐ Seldom
☐ Frequently

COMPUTER ATTITUDE SCALE

Below are a series of statements. There are no correct answers to these statements. They are designed to permit you to indicate the extent to which you agree or disagree with the ideas expressed. Place a checkmark in the space under the label, which is closest to your agreement or disagreement with the statements.

		Strongly Agree	**Slightly Agree**	**Slightly Disagree**	**Strongly Disagree**
1.	Computers do not scare me at all.	☐	☐	☐	☐
2.	I’m no good with computers.	☐	☐	☐	☐
3.	I would like working with computers.	☐	☐	☐	☐
4.	I will use computers many ways in my life.	☐	☐	☐	☐
5.	Working with a computer would make me very nervous.	☐	☐	☐	☐
6.	Generally, I would feel OK about trying a new problem on the computer.	☐	☐	☐	☐
7.	The challenge of solving problems with computers does not appeal to me.	☐	☐	☐	☐
8.	Learning about computers is a waste of time.	☐	☐	☐	☐
9.	I do not feel threatened when others talk about computers.	☐	☐	☐	☐
10.	I don’t think I would do advanced computer work.	☐	☐	☐	☐
11.	I think working and learning with computers would be enjoyable and stimulating.	☐	☐	☐	☐
12.	Learning about computers is worthwhile.	☐	☐	☐	☐
13.	I feel aggressive and hostile toward computers.	☐	☐	☐	☐
14.	I am sure I could do work with computers.	☐	☐	☐	☐
15.	Figuring out computer problems does not appeal to me.	☐	☐	☐	☐
16.	I’ll need a firm mastery of computers for my future work.	☐	☐	☐	☐
17.	It wouldn’t bother me at all to take computer courses.	☐	☐	☐	☐
18.	I’m not the type to do well with computers.	☐	☐	☐	☐
19.	When there is a problem with a computer run that I can’t immediately solve, I would stick with it until I have the answer.	☐	☐	☐	☐

		Strongly Agree	Slightly Agree	Slightly Disagree	Strongly Disagree
20.	I expect to have little use for computers in my daily life.	☐	☐	☐	☐
21.	Computers make me feel uncomfortable.	☐	☐	☐	☐
22.	I am sure I could learn a computer language.	☐	☐	☐	☐
23.	I don’t understand how some people can spend so much time working with computers and seem to enjoy it.	☐	☐	☐	☐
24.	I can’t think of any way that I will use computers in my career.	☐	☐	☐	☐
25.	I would feel at ease in a computer class.	☐	☐	☐	☐
26.	I think using a computer would be very hard for me.	☐	☐	☐	☐
27.	Once I start to work with the computer, I would find it hard to stop.	☐	☐	☐	☐
28.	Knowing how to work with computers will increase my job possibilities.	☐	☐	☐	☐
29.	I get a sinking feeling when I think of trying to use a computer.	☐	☐	☐	☐
30.	I could get good grades in computer courses.	☐	☐	☐	☐
31.	I will do as little work with computers as possible.	☐	☐	☐	☐
32.	Anything that a computer can be used for, I can do just as well some other way.	☐	☐	☐	☐
33.	I would feel comfortable working with a computer.	☐	☐	☐	☐
34.	I do not think I could handle a computer course.	☐	☐	☐	☐
35.	If a problem is left unsolved in a computer class, I would continue to think about it afterward.	☐	☐	☐	☐
36.	It is important to me to do well in computer classes.	☐	☐	☐	☐
37.	Computers make me feel uneasy and confused.	☐	☐	☐	☐
38.	I have a lot of self-confidence when it comes to working with computers.	☐	☐	☐	☐
39.	I do not enjoy talking with others about computers.	☐	☐	☐	☐
40.	Working with computers will not be important to me in my life’s work.	☐	☐	☐	☐

APPENDIX C: MATHEMATICS ATTITUDE INVENTORY

MATHEMATICS ATTITUDES INVENTORY
Richard Sandman
Minnesota Research and Evaluation Project
University of Minnesota

The following statements are about the study of mathematics. Please read each statement carefully and decide whether it describes the way you feel about mathematics. Then, find the number of the statement in the answer column (or on the answer sheet if one is provided), and blacken the response that best describes the way you feel. Be sure to blacken only one space for each statement. Be sure to answer every question. It should take about twenty minutes to complete the 48 statements of the inventory.

Remember to answer each statement according to the way you feel at the present time.

		Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
1.	Mathematics is useful for the problems of everyday life.	☐	☐	☐	☐
2.	Mathematics is something which I enjoy very much.	☐	☐	☐	☐
3.	I like the easy mathematics problems best.	☐	☐	☐	☐
4.	I don’t do very well in mathematics.	☐	☐	☐	☐
5.	My mathematics teacher shows little interest in the students.	☐	☐	☐	☐
6.	Working mathematics problems is fun.	☐	☐	☐	☐
7.	I feel at ease in a mathematics class.	☐	☐	☐	☐
8.	I would like to do some outside reading in mathematics.	☐	☐	☐	☐
9.	There is little need for mathematics in most jobs.	☐	☐	☐	☐
10.	Mathematics is easy for me.	☐	☐	☐	☐
11.	When I hear the word *mathematics*, I have a feeling of dislike.	☐	☐	☐	☐
12.	Most people should study some mathematics.	☐	☐	☐	☐
13.	I would like to spend less time in school doing mathematics.	☐	☐	☐	☐

		Strongly Agree	Agree	Disagree	Strongly Disagree
14.	Sometimes I read ahead in our mathematics book.	☐	☐	☐	☐
15.	Mathematics is helpful in understanding today’s world.	☐	☐	☐	☐
16.	I usually understand what we are talking about in mathematics class.	☐	☐	☐	☐
17.	My mathematics teacher makes mathematics interesting.	☐	☐	☐	☐
18.	I don’t like anything about mathematics.	☐	☐	☐	☐
19.	No matter how hard I try, I cannot understand mathematics.	☐	☐	☐	☐
20.	I feel tense when someone talks to me about mathematics	☐	☐	☐	☐
21.	My mathematics teacher presents material in a clear way.	☐	☐	☐	☐
22.	I often think, “I can’t do it”, when a mathematics problem seems hard.	☐	☐	☐	☐
23.	Mathematics is of great importance to a country’s development.	☐	☐	☐	☐
24.	It is important to know mathematics in order to get a good job.	☐	☐	☐	☐
25.	It doesn’t disturb me to work mathematics problems.	☐	☐	☐	☐
26.	I would like a job which doesn’t use any mathematics.	☐	☐	☐	☐
27.	My mathematics teacher knows when we are having trouble with our work.	☐	☐	☐	☐
28.	I enjoy talking to other people about mathematics.	☐	☐	☐	☐
29.	I like to play games that use mathematics.	☐	☐	☐	☐
30.	I am good at working mathematics problems.	☐	☐	☐	☐
31.	My mathematics teacher doesn’t seem to enjoy teaching mathematics.	☐	☐	☐	☐
32.	Sometimes I work more mathematics problems than are assigned in class.	☐	☐	☐	☐
33.	You can get along perfectly well in everyday life without mathematics.	☐	☐	☐	☐
34.	Working with numbers upsets me.	☐	☐	☐	☐

		Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**
35.	I remember most of the things I learn in mathematics.	☐	☐	☐	☐
36.	It makes me nervous to even think about doing mathematics.	☐	☐	☐	☐
37.	I would rather be given the right answer to a mathematics problem than to work it out myself.	☐	☐	☐	☐
38.	Most of the ideas in mathematics aren't very useful.	☐	☐	☐	☐
39.	It scares me to have to take mathematics.	☐	☐	☐	☐
40.	My mathematics teacher is willing to give us individual help.	☐	☐	☐	☐
41.	The only reason I'm taking mathematics is because I have to.	☐	☐	☐	☐
42.	It is important to me to understand the work I do in mathematics.	☐	☐	☐	☐
43.	I have a good feeling toward mathematics.	☐	☐	☐	☐
44.	My mathematics teacher knows a lot about mathematics.	☐	☐	☐	☐
45.	Mathematics is more of a game than it is hard work.	☐	☐	☐	☐
46.	My mathematics teacher doesn't like students to ask questions.	☐	☐	☐	☐
47.	I have a real desire to learn mathematics.	☐	☐	☐	☐
48.	If I don't see how to work a mathematics problem right away, I never get it.	☐	☐	☐	☐

This instrument was developed for research purposes by the Minnesota Research and Evaluation Project.

APPENDIX D: STUDENT SATISFACTION [WITH WBI] QUESTIONNAIRE

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Troy State University

Please read the statements below carefully. Fill in the circle by each statement that, for the most part, describes you. Answer each question as honestly as you can.

	Often	Sometimes	Seldom	I don't know
1. I am able to access a computer with an Internet connection to do my work for this class.	○	○	○	○
2. The resources I need for the Web lessons are readily available through the Internet.	○	○	○	○
3. I am satisfied with the degree of contact I have with my teacher when working through web-based lessons.	○	○	○	○
4. I am pleased with the success I am having with completing the web-based lessons.	○	○	○	○
5. My technology knowledge level is sufficient for learning in a web-based environment.	○	○	○	○
6. I am feeling somewhat isolated from the University setting by taking a class that places emphasis on learning through web-based lessons.	○	○	○	○
7. I would prefer to take more of my classes through Internet delivery.	○	○	○	○
8. Participating in a web-based course has allowed me more flexibility in my daily activities.	○	○	○	○
9. I would prefer more of the course materials in my traditional face-to-face classes to be in a web-based format.	○	○	○	○
10. I believe that working in a web instructional environment enables me to take a more active role in the learning process.	○	○	○	○
11. Communication with other students through email is a positive experience.	○	○	○	○
12. I find the online tutorials to be useful in helping me understand the material.	○	○	○	○
13. My web-based class is providing me with skills that I can use in other courses.	○	○	○	○
14. I believe that web instructional environment is preparing me for technology use in my profession.	○	○	○	○
	Yes	**No**		**I don't know**
15. I would be willing to take a web-based course again.	○	○		○
16. I would recommend a web-based course to a friend.	○	○		○

APPENDIX E: LESSON MODULE OUTCOMES AND ASSESSMENTS

Solving Quadratic Equations Lesson Module

Title of Unit

Solving Quadratic Equations

Grade Level

Postsecondary

Learning Goal

At the end of this unit, the learner will be able to:

- Define a quadratic equation.
- Recognize quadratic equations.
- Define three methods used to solve quadratic equations – factoring, completing the square, and using the quadratic formula.
- Obtain solutions to quadratic equations using the methods mentioned previously.

Learning Outcome(s)

Problem-solving

Objective(s)

Given access to a computer, the Internet, and Adam, the learner will be able to solve quadratic equations using the following methods: factoring, completing the square, and the quadratic formula.

Lesson: Solving Quadratic Equations

Solving Quadratic Equations

A **quadratic equation** is an equation of the form,

$$ax^2 + bx + c = 0,$$

where a, b, and c are real numbers, with $a \neq 0$. The condition, $a \neq 0$, ensures that the equation actually does have a x^2-term. When solving quadratic equations, we consider two cases: $b = 0$ and $b \neq 0$.

When $b = 0$, a quadratic equation is the form of $ax^2 - c = 0$ so we use the square root property to quadratic equations when $b = 0$.

Square Root Property

For any real number k, the equation $x^2 = k$ is equivalent to $x = \pm\sqrt{k}$.

If $k > 0$, then $x^2 = k$ has 2 real solutions.

$k < 0$, then $x^2 = k$ has no real solution.

$k = 0$, then 0 is the only solution to $x^2 = k$.

Examples: Solving $ax^2 - c = 0$

(a) Solve $x^2 - 9 = 0$ (b) $(2x-1)^2 = 0$ (c) $(x-3)^2 + 8 = 0$

Solutions:

(a) Use the square root property to solve $x^2 - 9 = 0$.

$$\begin{aligned} x^2 - 9 &= 0 \\ x^2 &= 9 \\ x &= \pm 3 \end{aligned}$$

Thus, the solution set for the equation $x^2 - 9 = 0$ is $\{\text{-}3, 3\}$.

(b) Using the square root property to solve $(2x-1)^2 = 0$, we get

$$\begin{aligned} (2x-1)^2 &= 0 \\ 2x-1 &= \sqrt{0} \\ 2x-1 &= 0 \\ 2x &= 1 \\ x &= \frac{1}{2} \end{aligned}$$

Thus, the solution set for the equation $(2x-1)^2 = 0$ is $\left\{\frac{1}{2}\right\}$.

(c) Use the square root property to solve $(x-3)^2 + 8 = 0$.

$$\begin{aligned} (x-3)^2 + 8 &= 0 \\ (x-3)^2 &= -8 \end{aligned}$$

Because the square of any real number is nonnegative, the equation $(2x-1)^2 = 0$ has no real solution.

For the case when $b \neq 0$, we can solve quadratic equations by factoring, completing the square, and using the quadratic formula.

Solving Quadratic Equations by Factoring

Zero Factor Property

If *A* and *B* are algebraic expressions, then the equation $AB=0$ is equivalent to the compound statement $A = 0$ or $B = 0$.

Examples:

Solve the following quadratic equations by factoring.

(a) $x^2 - x - 12 = 0$ (b) $(x+3)(x-4) = 8$

Solutions:

(a)
$$\begin{aligned} x^2 - x - 12 &= 0 \\ (x-4)(x+3) &= 0 \end{aligned}$$

Using the zero factor property, we get

$$\begin{aligned} x - 4 &= 0 \quad \text{or} \quad & x + 3 &= 0 \\ x &= 4 & x &= -3 \end{aligned}$$

Thus, the solution set is $\{-3, 4\}$.

(b) $(x+3)(x-4)=8$

First, multiply the left side using the FOIL method and subtract 8 from both sides.

$$\begin{aligned}(x+3)(x-4)&=8\\ x^2-x-12&=8\\ x^2-x-20&=0\\ (x-5)(x-4)&=0\end{aligned}$$

Using the zero factor property, we get

$$\begin{aligned}x-5&=0 \quad \text{or} \quad & x+4&=0\\ x&=5 & x&=-4\end{aligned}$$

Thus, the solution set is $\{\text{-4, 5}\}$.

Solving Quadratic Equations by Completing the Square

To complete the square of x^2+kx, add $\left(\frac{k}{2}\right)^2$ to both sides. That is, add the square of half the coefficient of x to both sides.

Examples:

Solve the following quadratic equations using completing the square.

(a) $x^2+6x+7=0$ (b) $2x^2-3x-4=0$

Solutions:

(a) First, subtract 7 from both sides and then add $\left(\frac{6}{2}\right)^2 = 9$ to both sides:

$$\begin{aligned} x^2 + 6x &= -7 \\ x^2 + 6x + 9 &= -7 + 9 \\ (x+3)^2 &= 2 \\ x + 3 &= \pm\sqrt{2} \\ x &= -3 \pm \sqrt{2} \end{aligned}$$

The solution set is $\left\{-3-\sqrt{2}, -3+\sqrt{2}\right\}$.

(b) First, divide both sides by the leading coefficient, which is 2.

$$x^2 - \frac{3}{2}x - 2 = 0$$

Now, add 2 to both sides and $\left(\frac{\frac{3}{2}}{2}\right)^2 = \left(\frac{3}{4}\right)^2 = \frac{9}{16}$ to both sides.

$$\begin{aligned} x^2 - \frac{3}{2}x &= 2 \\ x^2 - \frac{3}{2}x + \frac{9}{16} &= 2 + \frac{9}{16} \\ \left(x - \frac{3}{4}\right)^2 &= \frac{41}{16} \\ x - \frac{3}{4} &= \pm\frac{\sqrt{41}}{4} \\ x &= \frac{3}{4} \pm \frac{\sqrt{41}}{4} \end{aligned}$$

Thus, the solution set is $\left\{-\frac{3-\sqrt{41}}{4}, -\frac{3+\sqrt{41}}{4}\right\}$.

Solving Quadratic Equations using the Quadratic Formula

Quadratic Formula

The solution to $ax^2 + bx + c = 0$, with $a \neq 0$, is given by the formula,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a},$$

provided $b^2 - 4ac \geq 0$. If $b^2 - 4ac < 0$, there are NO REAL SOLUTIONS.

Example: Solve the quadratic equation, $x^2 + 8x + 6 = 0$, using the quadratic formula.

Solution: Since $a = 1, b = 8,$ and $c = 6$,

$$\begin{aligned} x &= \frac{-8 \pm \sqrt{(8)^2 - 4(1)(6)}}{2(1)} \\ &= \frac{-8 \pm \sqrt{64 - 24}}{2} \\ &= \frac{-8 \pm \sqrt{40}}{2} \\ &= \frac{-8 \pm 2\sqrt{10}}{2} \\ &= \frac{2\left(-4 \pm \sqrt{10}\right)}{2} \\ &= -4 \pm \sqrt{10} \end{aligned}$$

Thus, the solution set is $\left\{-4 - \sqrt{10}, -4 + \sqrt{10}\right\}$.

Solving Quadratic Equations

A **quadratic equation** is an equation of the form,

$$ax^2 + bx + c = 0,$$

where *a*, *b*, and *c* are real numbers, with $a \neq 0$. The condition, $a \neq 0$, ensures that the equation actually does have a x^2-term.

Solving Quadratic Equations by Factoring

Zero Factor Theorem

If *A* and *B* are algebraic expressions, then the equation $AB=0$ is equivalent to the compound statement $A = 0$ or $B = 0$.

Examples:

Solve the quadratic equation, $x^2 + 2x - 15 = 0$ by factoring.

Solutions:

(a)
$$\begin{aligned} x^2 + 2x - 15 &= 0 \\ (x-3)(x+5) &= 0 \end{aligned}$$

Using the zero factor theorem, we get

$$\begin{array}{ccc} x - 3 = 0 & \text{or} & x + 5 = 0 \\ x = 3 & & x = -5 \end{array}$$

Thus, the solution set is $\{\text{-5, 3}\}$.

A Special Quadratic Equation

For any real number *k,* the equation $x^2 = k$ is equivalent to $x = \pm\sqrt{k}$.

If $k > 0$, then $x^2 = k$ has 2 real solutions.

$k < 0$, then $x^2 = k$ has no real solution.

$k = 0$, then 0 is the only solution to $x^2 = k$.

Examples: Solve

(a) $x^2 = 361$ (b) $16x^2 = 49$

Solutions:

(a)
$$\begin{aligned} x^2 &= 361 \\ x &= \pm 19 \end{aligned}$$

Thus, the solution set for the equation $x^2 = 361$ is $\{-19, 19\}$.

(b) $16x^2 = 49$

$$\begin{aligned} 16x^2 &= 49 \\ x^2 &= \frac{49}{16} \\ x &= \pm\frac{7}{4} \end{aligned}$$

Thus, the solution set for the equation $16x^2 = 49$ is $\left\{-\frac{7}{4}, \frac{7}{4}\right\}$.

Solving Quadratic Equations by Completing the Square

To complete the square of $x^2 + kx$, add $\left(\frac{k}{2}\right)^2$ to both sides. That is, add the square of half the coefficient of *x* to both sides.

(1) $x^2 + kx + \left(\frac{k}{2}\right)^2 = \left(x + \frac{k}{2}\right)^2$

(2) $x^2 - kx + \left(\frac{k}{2}\right)^2 = \left(x - \frac{k}{2}\right)^2$

Examples:

Solve the following quadratic equations using completing the square.

(a) $x^2 - 8x + 11 = 0$ (b) $4x^2 + 20x + 13 = 0$

Solutions:

(c) First, subtract 11 from both sides and then add $\left(\frac{8}{2}\right)^2 = 16$ to both sides:

$$
\begin{aligned}
x^2 - 8x &= -11 \\
x^2 - 8x + 16 &= -11 + 16 \\
(x-4)^2 &= 5 \\
x - 4 &= \pm\sqrt{5} \\
x &= 4 \pm \sqrt{5}
\end{aligned}
$$

The solution set is $\left\{4-\sqrt{5}, 4+\sqrt{5}\right\}$.

(d) Solve $4x^2+20x+13=0$.

Solution: First, divide both sides by the leading coefficient, which is 4.

$$x^2+5x+\frac{13}{4}=0$$

Now, subtract $\frac{13}{4}$ from both sides and add $\left(\frac{5}{2}\right)^2=\frac{25}{4}$ to both sides.

$$\begin{aligned}
x^2+5x&=-\frac{13}{4}\\
x^2+5x+\frac{25}{4}&=-\frac{13}{4}+\frac{25}{4}\\
\left(x+\frac{5}{2}\right)^2&=\frac{12}{4}\\
\left(x+\frac{5}{2}\right)^2&=3\\
x+\frac{5}{2}&=\pm\sqrt{3}\\
x&=-\frac{5}{2}\pm\sqrt{3}
\end{aligned}$$

Thus, the solution set is $\left\{-\frac{5}{2}-\sqrt{3},\ -\frac{5}{2}+\sqrt{3}\right\}$.

Solving Quadratic Equations using the Quadratic Formula

Quadratic Formula

The solution to $ax^2 + bx + c = 0$, with $a \neq 0$, is given by the formula,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a},$$

provided $b^2 - 4ac \geq 0$.

If $b^2 - 4ac > 0$, then there exists has 2 real roots.

$b^2 - 4ac < 0$, then there exist no real roots.

$b^2 - 4ac = 0$, then there exists one root (double root).

Example: Solve the quadratic equation, $x^2 + 13x - 6 = 0$, using the quadratic formula.

Solution: Since $a = 5, b = 13,$ and $c = -6$,

$$\begin{aligned} x &= \frac{-13 \pm \sqrt{(13)^2 - 4(5)(-6)}}{2(5)} \\ &= \frac{-13 \pm \sqrt{169 + 120}}{10} \\ &= \frac{-13 \pm \sqrt{289}}{2} \\ &= \frac{-13 \pm 17}{10} \\ &= \frac{-30}{10}, \ \frac{4}{10} \\ &= -3, \ \frac{2}{5} \end{aligned}$$

Thus, the solution set is $\left\{-3, \frac{2}{5}\right\}$.

Solving Quadratic Equations

A **quadratic equation** is an equation of the form,

$$ax^2 + bx + c = 0,$$

where a, b, and c are real numbers, with $a \neq 0$. The condition, $a \neq 0$, ensures that the equation actually does have a x^2-term.

Solving Quadratic Equations

1. Solve by factoring
2. Solve by completing the square
3. Solve by quadratic formula: $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Note: A number (say a) is a **double root** or **root of multiplicity 2** if $x - a$ appears as a factor twice in a given solution.

Example: $(x-4)(x-4) = 0$ implies that $x = 4$ is a double root.

A Special Quadratic Equation

For any real number k, the equation $x^2 = k$ is equivalent to $x = \pm\sqrt{k}$.

If $k > 0$, then $x^2 = k$ has 2 real solutions.

$k < 0$, then $x^2 = k$ has no real solution.

$k = 0$, then 0 is the only solution to $x^2 = k$.

Examples: Solve

(a) $x^2 = 36$

(b) $(x+4)^2 = 31$

Solutions:

(a) $$\begin{aligned} x^2 &= 36 \\ x &= \pm 6 \end{aligned}$$

Thus, the solution set for the equation $x^2 = 36$ is $\{-6, 6\}$.

(b) $(x+4)^2 = 31$

$$\begin{aligned} (x+4)^2 &= 31 \\ x+4 &= \pm\sqrt{31} \\ x &= -4 \pm \sqrt{31} \end{aligned}$$

Thus, the solution set for the equation $(x+4)^2 = 31$ is $\left\{-4+\sqrt{31}, -4-\sqrt{31}\right\}$.

Solving Quadratic Equations by Completing the Square

To complete the square of $x^2 + kx$, add $\left(\frac{k}{2}\right)^2$ to both sides. That is, add the square of half the coefficient of *x* to both sides.

(1) $$x^2 + kx + \left(\frac{k}{2}\right)^2 = \left(x + \frac{k}{2}\right)^2$$

(2) $$x^2 - kx + \left(\frac{k}{2}\right)^2 = \left(x - \frac{k}{2}\right)^2$$

Note: When completing the square, the coefficient on the x^2-term MUST BE EQUAL to 1.

Examples:

Solve the following quadratic equations using completing the square.

(a) $x^2 - 5x$ (b) $x^2 - 5x + 3 = 0$

Solutions:

(a) Complete the square for $x^2 - 5x$.

$k = 5$, so $\left(\frac{k}{2}\right)^2 = \left(\frac{5}{2}\right)^2$

$$x^2 - 5x + \left(\frac{5}{2}\right)^2 = \left(x - \frac{5}{2}\right)^2$$

(e) Solve $x^2 - 5x + 3 = 0$.

Solution: Subtract 3 from both sides and add $\left(\frac{5}{2}\right)^2 = \frac{25}{4}$ to both sides.

$$x^2 - 5x = -3$$

$$x^2 - 5x + \frac{25}{4} = -3 + \frac{25}{4}$$

$$\left(x - \frac{5}{2}\right)^2 = \frac{13}{4}$$

$$x - \frac{5}{2} = \pm\frac{\sqrt{13}}{2}$$

$$x = \frac{5}{2} \pm \frac{\sqrt{13}}{2}$$

Thus, the solution set is $\left\{\frac{5-\sqrt{13}}{2}, \ \frac{5+\sqrt{13}}{2}\right\}$.

Solving Quadratic Equations using the Quadratic Formula

Quadratic Formula

The solution to $ax^2 + bx + c = 0$, with $a \neq 0$, is given by the formula,

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a},$$

provided $b^2 - 4ac \geq 0$.

If $b^2 - 4ac > 0$, then there exists has 2 real roots.

$b^2 - 4ac < 0$, then there exist no real roots.

$b^2 - 4ac = 0$, then there exists one root (double root).

Example: Solve the quadratic equation, $x^2 - 5x + 3 = 0$, using the quadratic formula.

Solution: Since $a = 1, b = -5,$ and $c = 3$,

$$\begin{aligned} x &= \frac{5 \pm \sqrt{(-5)^2 - 4(1)(3)}}{2(1)} \\ &= \frac{5 \pm \sqrt{25 - 12}}{2} \\ &= \frac{5 \pm \sqrt{13}}{2} \end{aligned}$$

Thus, the solution set is $\left\{ \frac{5 - \sqrt{13}}{2},\ \frac{5 + \sqrt{13}}{2} \right\}$.

Solving Quadratic Equations Assessment Quiz

Solve the following quadratic equations using the method indicated and choose the correct answer.

1. Solve $x^2 + 2x - 8 = 0$ by factoring.

   (a) $x = -2, 4$
   (b) $x = -2, -4$
   (c) $x = -4,\ 2$
   (d) $x = 2,\ 4$

2. Solve $x^2 - 10x + 5 = 0$ by completing the square.

   (a) $x = \pm\sqrt{20}$
   (b) $x = 5 \pm 2\sqrt{5}$
   (c) $x = 5 \pm \sqrt{30}$
   (d) $x = -5 \pm \sqrt{20}$

3 Solve $x^2 + 8x + 6 = 0$ using the quadratic formula.

   (a) $x = -4 \pm \sqrt{10}$
   (b) $x = 4 \pm \sqrt{10}$
   (c) $x = \pm\sqrt{10}$
   (d) $x = -2 \pm \sqrt{10}$

Solving Quadratic Equations Lesson Assessment

Solve each quadratic function using the method indicated. Please show all your work.

1. Solve $x^2 - x - 20 = 0$ by factoring.

2. Solve $x^2 + 6x + 1 = 0$ by completing the square.

3. Solve $2x^2 - 5x - 3 = 0$ using the quadratic formula.

Graphing Piecewise Functions Lesson Module

Title of Unit

Graphing Piecewise Functions

Grade Level

Postsecondary

Learning Goal

At the end of this unit, the learner will be able to:

- Define a piecewise function.
- Recognize piecewise functions.
- Sketch the graph of a piecewise function.
- Recognize a graph of a piecewise function.

Learning Outcome(s)

Problem-solving

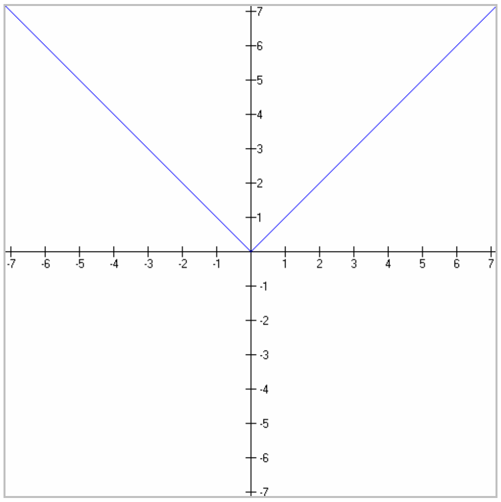
Objective(s)

Given access to a computer, the Internet, and Adam, the learner will be able to construct a graphical interpretation of a piecewise function.

Lesson: Graphing Piecewise-Defined Functions

Piecewise-defined functions are functions, where different formulas are used in different regions of the domain. The simplest example of a piecewise-defined function is the **absolute value function**, $f(x) = |x|$.

$$f(x) = |x| \text{ if and only if } f(x) = \begin{cases} x & \text{if } x \geq 0 \\ -x & \text{if } x < 0 \end{cases}$$



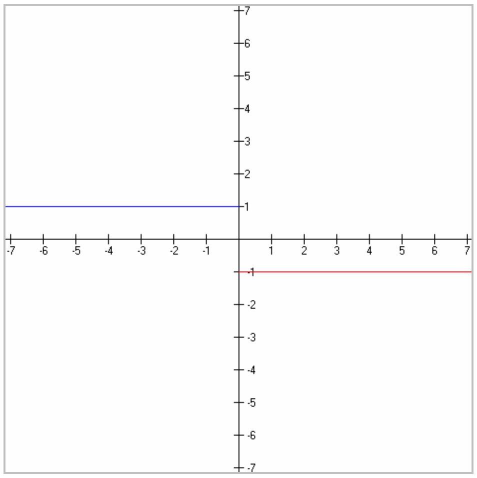
Examples: Sketch the graph of each function.

(a) $f(x) = \begin{cases} -1 & \text{if } x \geq 0 \\ 1 & \text{if } x < 0 \end{cases}$

(b) $f(x) = \begin{cases} 3 & \text{if } x \geq 0 \\ 3 + \sqrt{x} & \text{if } x < 0 \end{cases}$

Solutions:

(a) $f(x)=\begin{cases} -1 & \text{if } x \geq 0 \\ 1 & \text{if } x<0 \end{cases}$

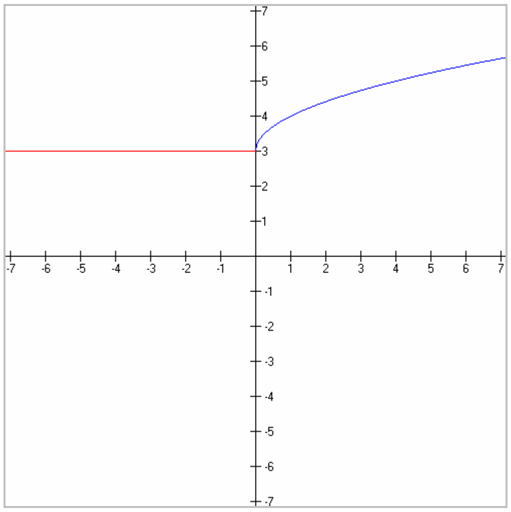


Notice that, for $x<0$, the graph is the horizontal line $y=1$. For $x \geq 0$, the graph is the horizontal line $y=-1$. Note that $(0,-1)$ is on the graph but $(0,1)$ is not, because when $x=0$, $y=-1$.

(b) $f(x)=\begin{cases} 3 & \text{if } x \geq 0 \\ 3+\sqrt{x} & \text{if } x<0 \end{cases}$

Make a table of ordered pairs using $y=3+\sqrt{x}$ for x less than 0.

x	0	1	4
$y=3+\sqrt{x}$	3	4	5

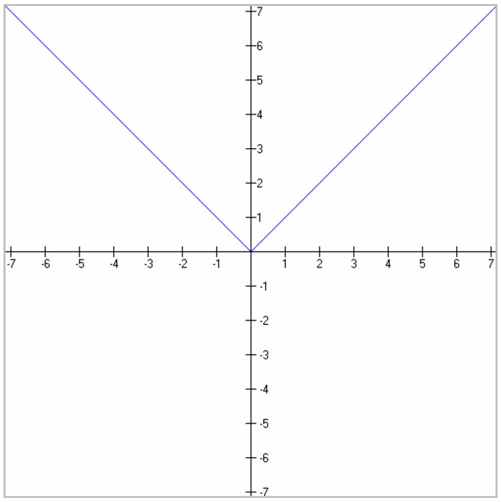


For $x < 0$, the graph is the horizontal line $y = 3$. For $x \geq 0$, the graph is a portion of the squared root function shifted 3 units up. Note that (0, 3) belongs to the graph $y = 3 + \sqrt{x}$, because when $x = 0$, $y = 3 + \sqrt{0} = 3$.

Graphing Piecewise-Defined Functions

Piecewise-defined functions are functions, where different formulas are used in different regions of the domain. The simplest example of a piecewise-defined function is the **absolute value function**, $f(x) = |x|$.

$$f(x) = |x| \text{ if and only if } f(x) = \begin{cases} x & \text{if } x \geq 0 \\ -x & \text{if } x < 0 \end{cases}$$

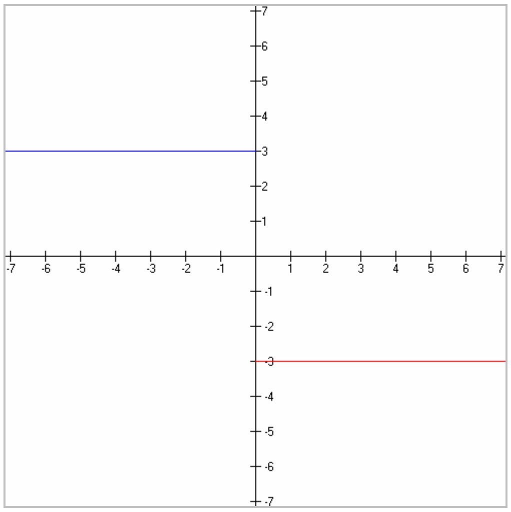


Examples: Sketch the graph of each function.

(a) $f(x) = \begin{cases} -3 & \text{if } x \geq 0 \\ 3 & \text{if } x < 0 \end{cases}$ (b) $f(x) = \begin{cases} x^2 - 4 & \text{if } -2 \leq x \leq 2 \\ x - 2 & \text{if } x > 2 \end{cases}$

Solutions:

(a) $f(x)=\begin{cases}-3 & \text{if } x\geq 0\\ 3 & \text{if } x<0\end{cases}$



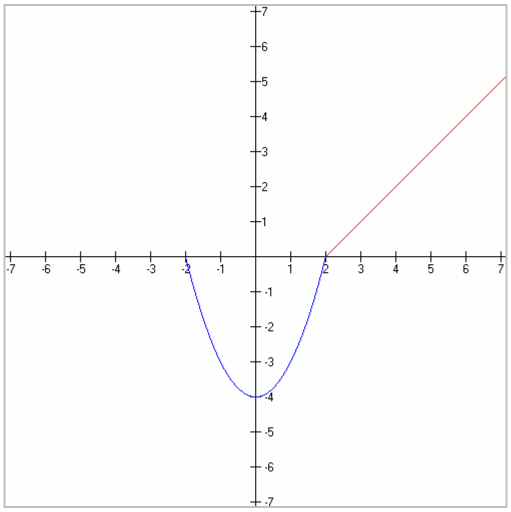
Notice that, for $x<0$, the graph is the horizontal line $y=3$. For $x\geq 0$, the graph is the horizontal line $y=-3$. Note that $(0,\text{-}3)$ is on the graph but $(0,3)$ is not, because when $x=0$, $y=-3$.

(b) $$f(x)=\begin{cases} x^2-4 & \text{if } -2\le x\le 2 \\ x-2 & \text{if } x>2 \end{cases}$$

Make a table of ordered pairs using $y=x^2-4$ for *x*-values between -2 and 2 and $y=x-2$ for $x>2$.

x	-2	-1	0	1	2
$y=x^2-4$	0	-3	-4	-3	0

x	3	4	5	6
$y=x-2$	1	2	3	4

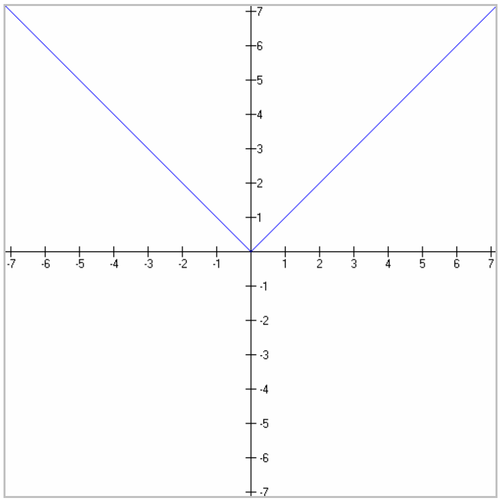


For the interval [-2, 2], the graph is a parabola shifted 4 units downward. For *x*>2, the graph is a straight line through points $(3,1),(4,2),(5,3)$, and $(6,4)$.

Graphing Piecewise-Defined Functions

Piecewise-defined functions are functions, where different formulas are used in different regions of the domain. The simplest example of a piecewise-defined function is the **absolute value function**, $f(x)=|x|$.

$$f(x)=|x| \text{ if and only if } f(x)=\begin{cases} x & \text{if } x\geq 0 \\ -x & \text{if } x<0 \end{cases}$$



Examples: Sketch the graph of each function.

(a) $f(x)=\begin{cases} x^2 & \text{if } x<3 \\ x-4 & \text{if } x\geq 3 \end{cases}$ (b) $f(x)=\begin{cases} -x & \text{if } 0\leq x<4 \\ \sqrt{x-3} & \text{if } x\geq 4 \end{cases}$

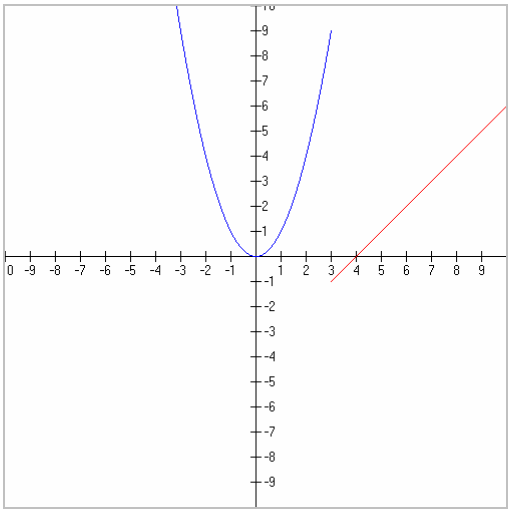
Solutions:

(a) $f(x) = \begin{cases} x^2 & \text{if } x < 3 \\ x - 4 & \text{if } x \geq 3 \end{cases}$

Make a table of ordered pairs using $y = x^2$ for x-values less than 3 and $y = x - 4$ for $x \geq 3$.

x	0	-1	1	-2	2
$y = x^2$	0	1	1	4	4

x	3	4	5	6
$y = x - 4$	-1	0	1	2



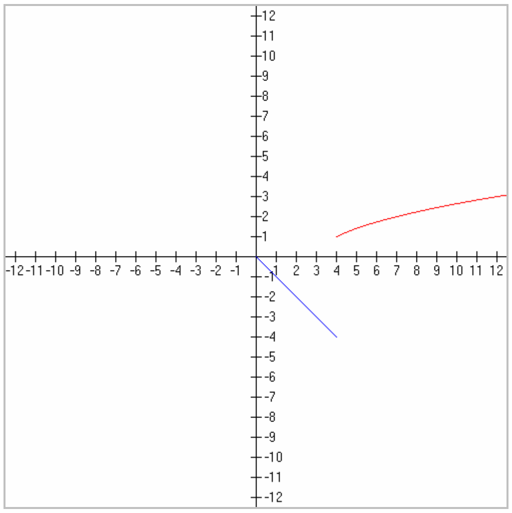
Notice that, for $x < 3$, the graph is a portion of a parabola. For $x \geq 3$, the graph is a straight line that goes through the points $(3,-1), (4,0), (5,1)$, and $(6,2)$.

(b) $$f(x) = \begin{cases} -x & \text{if } 0 \le x < 4 \\ \sqrt{x-3} & \text{if } x \ge 4 \end{cases}$$

Make a table of ordered pairs using $y = -x$ for x-values between 0 and 4 and $y = \sqrt{x-3}$ for $x \ge 4$.

x	0	1	2	3
$y = -x$	0	-1	-2	-3

x	4	7	12	19
$y = \sqrt{x-3}$	1	2	3	4



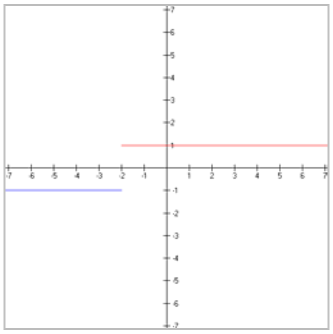
For the interval $[0,4)$, the graph is a straight line through points $(0,0), (1,-1), (2,-2)$, and $(3,-3)$. For $x \ge 4$, the graph is a portion of the square root function that is shifted 3 units to the right.

Graphing Piecewise Functions Assessment Quiz

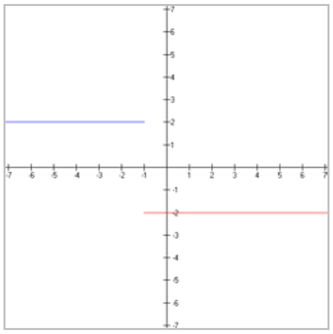
Sketch the graph of each function and circle the letter that corresponds to the right answer.

1. $$f(x) = \begin{cases} 2 & \text{if} \quad x < -1 \\ \text{-}2 & \text{if} \quad x \geq -1 \end{cases}$$

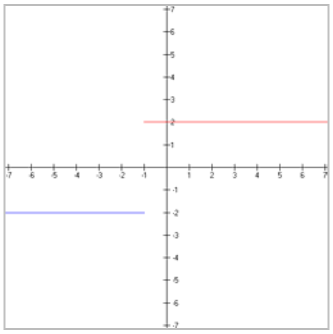
(a)



(b)

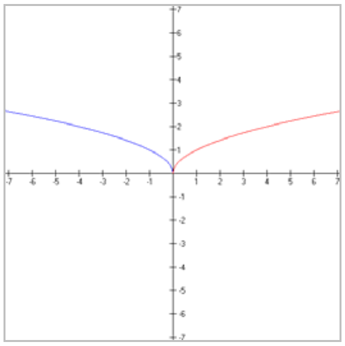


(c)

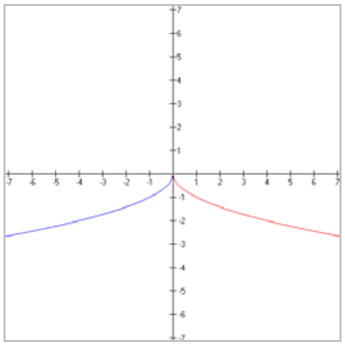


2. $$f(x) = \begin{cases} \sqrt{x} & \text{if} \quad x \geq 0 \\ \sqrt{-x} & \text{if} \quad x < 0 \end{cases}$$

(a)



(b)



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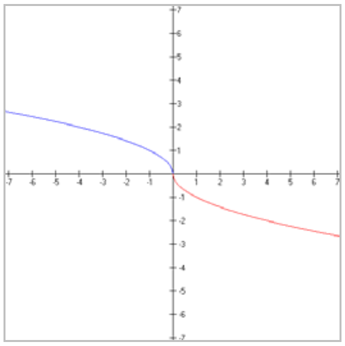
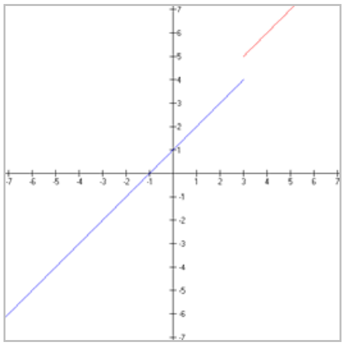


3. $$f(x) = \begin{cases} x+1 & \text{if} \quad x \geq 3 \\ x+2 & \text{if} \quad x < 3 \end{cases}$$

(a)



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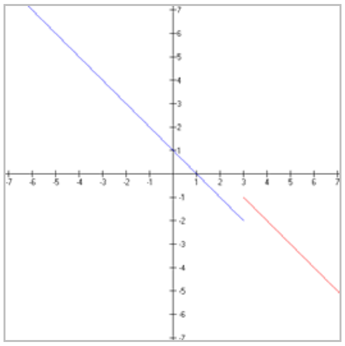

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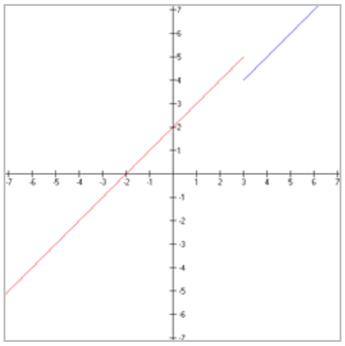
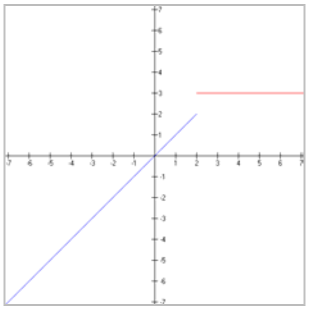


Graphing Piecewise Function Lesson Assessment

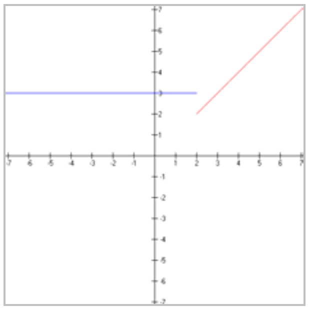
Sketch the graph of each function and circle the letter that corresponds to the right answer.

1. $$f(x) = \begin{cases} 3 & \text{if} \quad x < 2 \\ \text{x} & \text{if} \quad x \geq 2 \end{cases}$$

(a)



(b)



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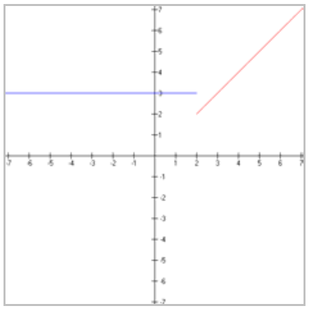
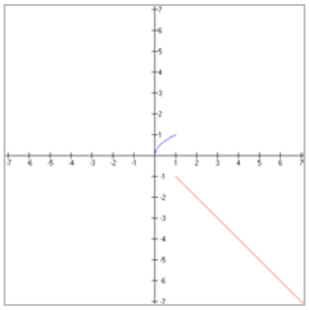
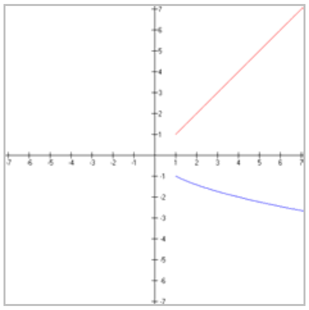


2. $$f(x)=\begin{cases}\sqrt{x} & \text{if } x\geq 1\\ -x & \text{if } x<1\end{cases}$$

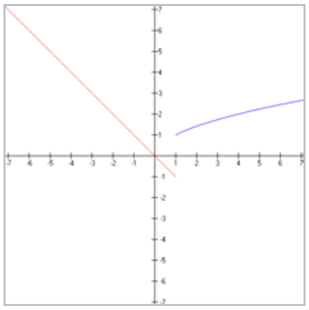
(a)



(b)

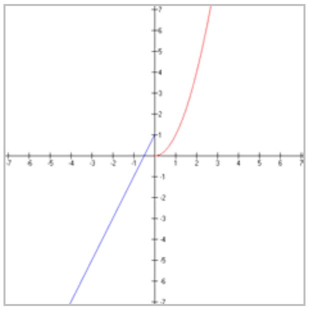


(c)

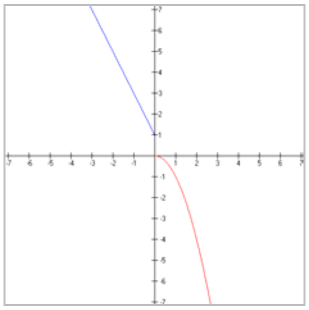


3. $$f(x) = \begin{cases} 2x+1 & \text{if} \quad x < 0 \\ x^2 & \text{if} \quad x \geq 0 \end{cases}$$

(a)



(b)



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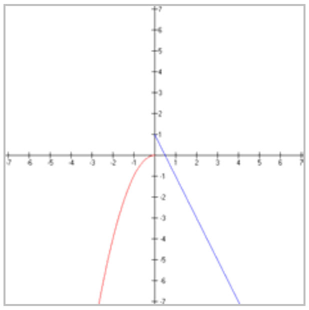

Lesson Scoring Rubric

	Excellent **(4)**	Very Good **(3)**	Good **(2)**	Fair **(1)**	Very Poor **(0)**
Response	A complete response with a detailed explanation; made no math errors; showed complete understanding of the questions, mathematical ideas, and processes; clear diagram or sketch with labels.	Good solid response with clear explanation; made no major math errors or serious flaws in reasoning; showed substantial understanding of the problem, ideas, and processes; clear diagram or sketch with no labels.	Explanation was unclear, made some serious math errors or flaws in reasoning; response showed some understanding of the problem; inappropriate or unclear diagram.	Missed key points; made major math errors or serious flaws in reasoning; response showed a complete lack of understanding for the problem; no diagram or sketch.	Incorrect or inadequate calculations and representations; crossed out/erased, illegible, or impossible to interpret; no work shown at all

APPENDIX F: EXAM PROBLEMS

Question #1:

Solve the quadratic equation $4x^2 - 12x - 11 = 0$

(i) using the quadratic formula **AND**

(ii) by completing the square

Question #2:

Sketch the graph of *f*.

$$f(x) = \begin{cases} 3 & \text{if} \quad x < -2 \\ -x + 1 & \text{if} \quad |x| \le 2 \\ -3 & \text{if} \quad x > 2 \end{cases}$$

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