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Effects of Computer-displayed Animation on Achievement and Attitudes in Mathematics Computer Based Instruction

By
© Brent Poohkay

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education.

In Instructional Technology
Department of Adult, Career And Technology Education

Edmonton, Alberta
Spring, 1994

ISBN 0-612-11329-9

UNIVERSITY OF ALBERTA

RELEASE FORM

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TITLE OF THESIS: Effects of Computer-displayed Animation on Achievement and Attitude in Mathematics Computer Based Instruction

DEGREE: Master of Education

YEAR THIS DEGREE GRANTED: 1994

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Effects of Computer Displayed Animation on Achievement and Attitudes in Mathematics Computer Based Instruction submitted by Brent Poohkay in partial fulfillment of the requirements for the degree of Master of Education.

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ABSTRACT

Computer Based Instruction (CBI) has existed since the early 1960's and since then has probably been one of the most studied instructional methods in history. However, only a small handful of studies have been conducted that examine the effect of computer-displayed animation. Computer-displayed animation is now becoming a popular feature of CBI as it can be both created and played back on low cost desktop microcomputers that are now widely available. In [illegible], animation was a capability of only mainframe computers or [illegible]sive microcomputer workstations.

The purpose of this study was to examine the effect of mathematics computer based instruction lessons using text alone, text and graphics, and text and animation on achievement and attitude of subjects grouped by gender and prior achievement. Three versions of the same computer based instruction lesson were prepared that used computer-displayed animation and text, stationary graphics and text, and text alone to convey lesson content. The topic of the mathematics lesson was the construction of resultant triangles using only a compass and straightedge when given separate line segments, or line segments and an included angle(s).

The present study found that subjects who received the treatment that contained the CBI lesson with computer-displayed animation scored

significantly higher on the lesson posttest than those subjects who received other treatments. As well, this study found that subjects who received the treatment that contained the CBI lesson with computer-displayed animation had significantly more positive attitudes toward learning mathematics by computer than the text only CBI treatment and equivalent scores to the stationary graphics treatment. These results suggest that computer-displayed animation is beneficial to subject learning outcomes as measured by achievement and attitude.

Within the computer-displayed animation treatment group, there was no significant difference in posttest score between males and females. This result may be misleading, however, due to the small number of males who participated in the study.

For low pretest achievers, the use of computer-displayed animation and text to convey lesson content was found to be more beneficial than stationary graphics and text or text alone. The same finding held true for high pretest achievers.

ACKNOWLEDGMENTS

I express my heartfelt gratitude to the following individuals:

- To Dr. M. Szabo, who first introduced me to the fascinating field of Instructional Technology and subsequently served as my Thesis Supervisor. Without his continual support, involvement, interest, and positive attitude, this thesis would not have been possible.

- To Dr. G. Cathcart who was instrumental in helping provide the sample for this study and for his helpful and positive contributions on the thesis committee.

- To Dr. D. Collett for his thoughtful contributions and advice serving on the thesis committee.

- To Brett McConkey, for his much needed assistance with developing and adapting the computer based materials used in this study.

- To Christine, for providing constant love and support.

- To my family, for all their help and support throughout the years.

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CHAPTER I: INTRODUCTION

Background

Computer Based Instruction (CBI) has existed since the early 1960's and since then has probably been one of the most studied instructional methods in history. For example, the ERIC on-line database of research articles for the years 1982 to 1993 contains more than *ten thousand* articles that contain computer-assisted-instruction as an identifier. There is now a general consensus that computer based instruction can be an effective tool for the delivery of instruction. Consistent, positive research results [Kulik, Kulik & Cohen, 1980], combined with a growing installed base of technology has led to computer assisted instruction becoming a more widely accepted form of delivery for instruction.

The power of today's microcomputers is advancing at an accelerating rate that at times seems difficult to follow. The capabilities of what can be produced by these now abundantly found and inexpensive computers seems only limited by the imagination. One of the features that seems to stimulate and excite users and developers alike is computer-displayed animation. From the most complex of three-dimensional rendered objects spinning across the screen, or simply a car zooming through the computer display, animation seems to please all. One must only peruse through some of the software titles currently available to see that computer-displayed animation is now becoming a very popular feature of computer based instruction and other forms of instructional technology. However, no reliable empirically tested base of support for the use of animation in CBI has yet been established. To date, there is only a handful of research studies that specifically examine the effects that animation have on learning as measured by achievement and attitude. In these studies, there is only a marginal amount of empirical data that support the assumption that animation positively affects the learner. This could be due to the fact that few studies in this area have been conducted to date, and also the fact that there are questions as to the reliability of the results of many of the existing studies [Rieber, 1990].

Problem Statement

The purpose of this study is to conduct empirical research to investigate the use of computer-displayed animation for instructional purposes. More specifically, this study will examine the effect of mathematics computer based instruction lessons using text alone, text and graphics, and text and animation on achievement and attitude of subjects grouped by gender and prior achievement.

Sub-problems

In the course of this study, there are four sub-problems that are addressed. The first sub-problem examines if students who receive the treatment that uses computer-displayed animation will obtain higher achievement scores than those subjects who receive the other treatments.

This will test if the addition of computer-displayed animation will increase learning.

The second sub-problem examines if students who receive the treatment that uses computer-displayed animation will obtain higher scores on a post lesson attitude survey than those subjects who receive the other treatments.

The third sub-problem examines if computer-displayed animation has differing effects on subjects based on gender. If so, will that effect occur in achievement score, attitude score, or both?

The final sub-problem investigates the most effective method of content display for low mathematics achievers. It also examines the most effective method of content display for high mathematics achievers. The question of how animation will affect subjects with different levels of mathematics ability will be addressed here.

Limitations

There are a number of limitations of this study. First, all subjects in this study are adults, aged eighteen and above and results may not reflect individuals outside this age group.

Secondly, the data for this study were collected in one sitting, with sitting time ranging anywhere from forty to sixty minutes. With only one sitting, it is not possible to generalize what effect animation will have over longer, more sustained periods of time, or what effect it could have over multiple lessons. As well, there is no test as to the level of retention of content over time that will be achieved by subjects who encounter animation in their CBI lesson.

There is also the possibility of an effect of novelty where subjects may pay more attention to the lesson simply because of the fact subjects may be experiencing computer-displayed animation for the first time and not because it is any more instructionally effective.

The final identified limitation of this study was that some subjects may have felt that they were under a time pressure to complete all components of the study. Although class time was one hour, the participants were told they could stay as long as they needed to complete the work given. However, subjects may have had other classes or commitments immediately following data collection that may have affected their performance.

Delimitations

This study is limited to the use of animation in mathematics computer based instruction. As well, this study does not examine the effects of computer-displayed animation crossed with other features of computer based instruction such as multiple levels of practice or feedback.

This study does not examine, nor is it concerned with, the overall effectiveness of computer based instruction in mathematics or non-mathematics applications.

This study examines computer-displayed animation when used to directly display lesson content. It does not examine animation in use as feedback, or as a non-content related motivational device.

Definition of Terms

Several terms and phrases used in this study should be defined to promote clarity. These words will be defined operationally so as to fall within the framework of this research study.

Attitude is a dependent variable for this study and it refers to reported Likert Scale scores of subjects on a computer administered attitude survey given after the computer based mathematics lesson and post-lesson achievement test.

Computer Based Instruction is operationally defined as the style of instructional delivery for this study in which the subject receives instruction via the computer only.

Computer-displayed Animation is a series of slightly different still frames or pictures that when played in succession on a computer display, give the illusion of motion. All graphic images in a computer-displayed animation have been created with and then played back by a computer. Rieber [1990] has identified three areas in which animation has been used in instruction. Generally, these three categories are attention-gaining, presentation, and practice.

Computer Graphics are still pictorial displays that are created and displayed on a cathode ray tube monitor of a computer.

Graphic User Interface is an environment in which a computer user uses pictures and icons to control a computer rather than textual commands.

Mathematics Achievement is the main dependent variable for this study and is operationally defined as the subject's achievement score on the post test.

Math 13 CBI is a computer based instruction software package that covers the content of the entire High School Grade Ten Mathematics Curriculum from a western Canadian province.

Significance of the Study

Computer-displayed animation is now a popular feature of instructional computer software. Siliauskas [1986, p. 83] summarizes best when she states, "It is a fact that we will have increasing access to presentation and response capabilities that have never before been possible. Guidelines for the use of these capabilities are not yet available, and on the basis of the current state of research in the field, we can predict that such assistance will take time in arriving." This statement seems to have most significance for the computer based training developer, and the educator, who is the end user of the product. Both these groups need to know the effect of computer-displayed animation to use technology to maximize positive outcomes for the learner .

The growing popularity of graphic user interfaces and animation is unprecedented and shows no signs of slowing. Animation is now a popular feature of instructional computer software yet there is little evidence to support its instructional value. Furthermore, if animation does have a positive effect on the learner, a set of guidelines needs to be developed that will outline this use.

This study investigated the effect of computer-displayed animations on the learner in terms of achievement and attitude in a mathematics computer based lesson. Through this process, some of the advantages and/or disadvantages of animations were identified. The results of this study may impact how computer-displayed animations will be used in instructional courseware.

CHAPTER II: LITERATURE REVIEW

Introduction

This chapter first gives a brief background of computer based instruction for reference purposes. A brief history of computer displays is also provided to show the drastic improvements in display technology over the past two decades. Finally, the literature regarding computer-displayed animation and its use in computer based instruction is reviewed.

Computer Based Instruction

Computer based and computer assisted instruction have been the subject of a large number of research studies. Since the 1960's, research in this area has generally seemed to support the conclusion that computer based instruction is an effective means of instructional delivery.

In the 1990's, the power and capabilities of microcomputers is advancing at a rate that does not show signs of slowing. High quality graphic images, animations, digital video, and three-dimensional rendered objects are only some of the features that are now available on even low cost machines. Processing speed and power has increased as well. At the same time power and capabilities have been increasing, price has been decreasing in a highly competitive market. Microcomputers can now be found in large numbers across North America. Positive research results, combined with a large installed base of technology suggest that computer based instruction is a viable vehicle for delivery of educational materials. However, with new capabilities of computers, the process of how instruction could be delivered becomes more complex [Rieber, 1989].

After an extensive review of fifty-nine CBI related research studies for college level learners, Kulik, Kulik, and Cohen [1980] found that overall, CBI "made small, but significant contributions to the course achievement" [p.525]. More specifically, they found that if a learner who normally scored at the 50^{th} percentile using traditional instruction would have instead received instruction via CBI, they would have scored at the 60^{th} percentile on an achievement exam covering course content. There was also a positive effect towards attitude towards the instruction in relation to conventional methods. The biggest impact of CBI was that the time needed to cover content was significantly reduced using CBI.

Edwards et al. [1975] also found in an extensive review that CAI was effective in terms of learner achievement on content based tests, savings of time needed to cover content, and that traditional instruction supplemented with CAI is more effective than traditional instruction alone.

Similarly, Burns and Bozeman [1981] found that specifically in mathematics, an instructional program that either supplemented or replaced conventional instruction with tutorial type CBI was significantly more effective than the conventional program alone. As well, drill and practice type CBI to supplement instruction was also found to significantly increase achievement scores of subjects. This effect was found to be true for both elementary and secondary level students. Disadvantaged students were found to significantly benefit from mathematics CBI. Furthermore, it was found that there was no relationship between experimental design and the outcomes of these types of studies. Burns and Bozeman concluded [p. 37] that "an analysis and synthesis of many studies do point to a significant enhancement of learning in instructional environments supplemented by CAI, at least in one curricular area–mathematics."

It is important to keep in mind that researchers were finding positive effects of CBI, even in its infancy. As well, these reviews are somewhat dated. Technology has improved vastly over the last fifteen years, and with those improvements have come improvements in both quality and quantity in the type of resources and interactions that can be implemented into CBI by the instructional designer. With this increase in instructional features, one could postulate that the size of these positive effects of CBI has stayed constant, or has possibly grown. In a more recent review of the literature, Forsyth [1991] also found that computer based instruction has been generally shown to produce positive effects for learners in relation to traditional instruction.

History of Computer Based Instruction Displays

This section is intended only to provide a general background of the history of computer displays to illustrate that animation is now a viable option for presentation displays. It is also intended to illustrate that technology is improving very rapidly, and with these improvements come a variety of new options for modes of display on a computer monitor. From this brief history, it may also be possible to see that what could be defined as computer-displayed animation ten years ago might not qualify as computer-displayed animation using the technology of today.

IBM 1500

The earliest CBI systems used print based output typed onto a continuous roll of paper. The first cathode ray tube monitors had limited resolution and no color or graphic output beyond numbers and upper case letters. The IBM 1500 represented a large improvement over those first technologies.

The IBM 1500 was a computer system which offered fully integrated multimedia features and could be supplied by a single manufacturer [Hunka & Buck, 1992]. This system was the first of its kind, being released in the mid 1960's. Only twenty-five of the systems were ever built as they were extremely expensive. The full system consisted of up to thirty-two student stations that each contained a magnetic media audio tape system, a rear projection 16 mm film screen, a cathode ray tube

(CRT) monitor, keyboard, and light pen. The concept of an integrated multimedia system apparent in the IBM 1500 was ahead of its time as only today are we now seeing widespread integration of multimedia components in a single system. The only computer-displayed graphics available on the IBM 1500 were black and white medium resolution visuals. The 1500's CRT was divided into a series of blocks on the screen that could be addressed by x and y coordinates. These blocks could be illuminated in one color, white. The programmer then had to use a series of these small electronic "blocks" to build a picture. Because these blocks were the only tools available, corners and edges of objects appeared jagged and images looked unrealistic.

The PLATO System

The PLATO system was another system of that era that had the capability of displaying animation. It used a different sort of display, a plasma gas display, but was still based on the "block" graphics that could be found on the IBM 1500, but at a better resolution and significantly greater processing power.

Apple II and IBM PC Microcomputers

The Apple II system, released in 1979 and the IBM PC from the same period brought many of the features found only in larger, more expensive systems into many of the homes and schools of North

America at a reasonable price. These systems used color graphics that would be of low resolution compared to today's microcomputers.

Microcomputers of the early 1990's

Today's desktop computer system is as powerful as the most powerful computer that existed twenty years ago. At this rate of progression, it is difficult to even imagine the power of the microcomputer twenty years from now. It is now common to have a desktop computer that can display twenty-four bit color that is capable of displaying over fourteen million different colors on the computer display. Not only can these colors be displayed, but they can be altered in a fraction of a second. Desktop video is an example of how display performance has increased over the last three years. QuickTime™ is a format that allows a user to save video as a computer file and display it on a computer monitor. Upon QuickTime's release, it was benchmarked for video playback at twelve frames per second in a window that was one hundred sixty pixels wide and one hundred twenty high. QuickTime Version 2.0 is soon to be released and it is capable of displaying fifteen frames per second on a full screen that is six hundred forty by four-hundred eighty pixels in size. This represents an increase of performance of over eight hundred percent in only three years! With the 1994 release of powerful Reduced Instruction Set Computing (RISC) computer chips by a joint effort of Apple Computers, IBM, and Motorola, it is not unreasonable that this same leap in performance will occur again.

Pictorial Strategies and Learning

Two types of pictorial strategies have been identified for use in the instructional process; experimenter-provided and learner-displayed [Alesandrini & Rigney, 1981]. Research suggests that in general, static graphics and visuals can positively influence learning whether in a computer based instruction environment or not. This applies to both adults [Alesandrini, 1984] and children [Pressley, 1977]. More specifically, studies generally show that graphics help the learner to better recall the information that was displayed in the picture [Alesandrini, 1985]. No matter whether the graphics are representational, analogical, or abstract, graphics were still found to enhance learning [Alesandrini, 1985].

In one study [Rigney & Lutz, 1976], researchers used graphics in a computer based lesson and then encouraged subjects to use their own mental imagery to help them remember course content. They found that "supplementing verbal description with graphic analogies results in better learning and more positive student attitudes than presenting only verbal description" [Rigney & Lutz, 1976, p. 310]. Furthermore, their findings "support the view that external imagery also can facilitate complex concept learning" [Rigney & Lutz, 1976, p. 311]. This suggests that in a computer based instruction setting, the designer should not only make visuals relevant to course content, but should also encourage students to form their own visualizations.

One study found that pictures have the potential to be distractors in reading. Willows [1978] found that in children's reading books, "Words were read more slowly whenever pictures were present." As well, "Unrelated pictures produced more interference than related pictures" [Willows, 1978, 255]. These findings were consistent with others of the time [Rosinski et al., 1975]. In a print based book, the author has no control over the order in which the contents of a page are attended to. When a student turns a book page, the pictures and text may compete for student attention. However, in CBI this factor can be controlled. The picture alone can be shown first and text can be added only after the student has attended to the visual or vice versa. A combination of components of text and graphics can be presented as well. Willows also found that pictures that tend to be complex may also interfere with reading because they represent too many components of the text. Therefore, when students come to a word they do not know and look to the visual for aid as to its meaning, the aspects of the visual that do not relate to the text may mislead the student in terms of its meaning [Willows, 1978]. This suggests that for CBI applications pictures should not be complex in nature and should relate directly to the text unless the student is informed as to which aspects of the visual they should be attending to. As well, this suggests that it may be important to remove as many student misconceptions as possible before presenting new subject matter. Hypermedia systems seem to take advantage of this finding as they allow students to see graphical representations of words, or, conversely, see textual examples and explanations of graphical images upon demand.

Research has also shown that pictures can be used effectively in review strategies compared to verbal presentation and review alone [Alesandrini & Rigney, 1981]. This could have implications for remedial help and instructional feedback for questioning. Based on this finding, students in a CBI lesson, who are having difficulty with content may benefit greatly from the existence of a related visual in the feedback they receive to questioning. As well, this finding could indicate that visuals may improve understanding and performance in practice activities.

In terms of using static graphics in positive feedback messages to students, it was found that "...graphic feedback was not differentially effective at maintaining interest in the use of the computer for studying spelling lists" [Surber & Leeder, 1988, p. 16]. Further, it was found that "If a graphic feedback effect does exist, it is not so overwhelmingly large that it can be detected by simple observation" [Surber & Leeder, 1988, p. 16]. There are some possibilities as to why this and other studies have found these results. Firstly, there is the issue of the quality of the graphic. Many of these studies were conducted using older, less powerful microcomputers like the Apple II series computer as a delivery platform for instruction. Graphics on these computer systems are of very low resolution and have poorer color quality compared to the technology of today. It is possible that these lesser quality graphics affected the results. As well, the same small sets of graphics were used repeatedly throughout a study. The reason for this was that computer graphics of the past placed much heavier demands on the operating system's memory and available disk space compared to similar graphics on today's microcomputers. Students may have found the graphics to be motivating in the beginning, but after a period of time in which they view the same feedback displays over and over, this motivating effect could be lost due to the boredom of repetition.

In another study conducted on a PLATO platform, researchers found that the use of graphic analogies in a CBI lesson yielded positive effects in terms of better attitudes towards lesson content and more enjoyable experiences with the CBI lesson [Rigney & Lutz, 1976]. The fact that this research found that static visuals alone induced more positive attitudes towards course content might be reason enough for an instructional designer to use them. Any factor that increases student interest and motivation should be utilized in a CBI lesson wherever feasible. As well, students using the lesson with graphic analogies reported using more mental imagery when learning content [Rigney & Lutz, 1976].

Viability of Animation Today

In contrast to the systems listed above, many of today's microcomputers can display even the most complex of animations. Screen density ranges from seventy-two pixels per inch of screen display space and above.

Screen displays will show twenty-four bit color. With powerful processors, computers can display animation or video at thirty frames per second, which is NTSC or television standard. The power of microcomputers available today is unprecedented and is sure not only to continue, but also to increase in magnitude.

Animation in Computer Based Instruction

Rieber [1990] conducted a review of the research regarding use of computer-displayed animation. Analyses were made of the studies available at the time that dealt with animation and its effects on the learner. Rieber himself had authored or co-authored five of those twelve studies. Based on his review, Rieber made three recommendations in terms of how animation could be effectively used in computer based instruction. Baek & Layne [1988] have made similar recommendations.

> Recommendation 1: Animation should be incorporated only when its attributes are congruent to the learning task [Rieber, 1990, p. 79].

This recommendation recognizes that animation that is superfluous in regards to subject matter might interfere with the learning task. Where possible animation should relate most directly to content. However, Rieber states that animation can be effectively used as an attention gaining device [Rieber, 1990], and references Gagné [1985] noting that attention gaining can be an important initial part of the instructional process.

> Recommendation 2: Evidence suggests that when learners are novices in a content area, they may not know how to attend to relevant cues or details provided by animation [Rieber, 1990, p. 82].

This is an important consideration in terms of courseware design. In one study, researchers had used animation to illustrate Newton's laws of motion [Rieber, 1989]. However, students were unable to differentiate between the speed of animated objects because they were not expecting such differences. They were instead more concerned with the direction of the objects. Direction was not an important component of what was being taught.

> Recommendation 3: Animation's greatest contributions to CBI may lie in interactive graphic applications (e.g., interactive dynamics) [Rieber, 1990, p. 82].

Rieber [1990] is not alone [Siliauskas, 1986] in suggesting that interactivity is an important aspect when using animation in a computer based instruction lesson. However, the time needed to develop interactive animations greatly exceeds animations that are simply viewed. For this reason, there are few commercially available computer based instruction lessons with truly interactive animations. As well, there has been no testing of this type of animation to date. Rieber [1991] has also sought to establish theoretical principles on which effective animation used in an instructional context can be based on.

In order not to confound the results of a study, Baek & Layne [1988] have developed three guidelines which should be considered when conducting animation research.

> First, the definition of terms needs to be clarified. Second, the careful use of color, graphics and animation to draw student attention is required, and they should illustrate the important features of the material being presented. Third, when graphics and animation are used, it is useful to first remove any possible misconceptions and to help students notice that the characteristics of the graphics and animation are related to the subject matter [Baek & Layne, 1988, p. 131].

This study found that the group that used the CAL lesson with animation scored higher on a post lesson achievement test than those who used the lesson with graphics or text [Baek & Layne, 1988].

Mayton [1991] conducted a study with seventy-two undergraduate university students using animated and non animated computer based instruction lessons. This study found that animation can be useful in teaching dynamic processes [Mayton, 1991]. Students using the animated version of the lesson scored higher on an achievement posttest than those who used the version with static graphics. This effect appeared to be maintained over a period of time as subjects were retested one week later and the animation group scored higher once again [Mayton, 1991].

Another interesting finding was that CBI containing animation allowed students to complete lessons more quickly than those with static graphics or text alone [Baek & Layne, 1988]. Another study found that although animation did not necessarily affect learning, it did decrease the time needed to retrieve that information from long term memory and reconstruct it in short term memory [Rieber & Boyce, 1990]. The authors concluded that "...providing adults with animated presentations may be unnecessary to increase learning when given verbal presentations which are carefully designed with highly imaginable explanation and examples and when these students are prompted to form such internal images" [Rieber & Boyce, 1990, p. 50]. One ramification of this statement is that some learners may benefit from visualizing their own animated event based on thoughtfully presented textual based examples. Personally created visual images can be more powerful and meaningful to the learner than images created by a CBI designer and displayed by a computer, based on the results of this study.

To summarize, Rieber & Boyce found that with adults, learning was "not influenced more by one type of presentation strategy than another" [Rieber & Boyce, 1990, p. 50]. These findings are not consistent with Baek & Layne [1988] and Mayton [1991] who were also testing with adults. However, in the Rieber & Boyce study, time needed to reconstruct information in short term memory from long term memory was decreased.

Interestingly, even though only a small number of studies have been done in this area to date, there has been speculation as to the reliability of results. In Rieber's review of animation research, five of the twelve studies are categorized as having "no evidence of content validity and test reliability" [Rieber, 1990, p.80].

Summary

The literature indicates that with increased processing power and better graphics, delivery choices for computer based instructional designers have become more complex.

> It is a fact that we will have increasing access to presentation and response capabilities that have never before been possible. Guidelines for the use of these capabilities are not yet available, and on the basis of the current state of research in the field, we can predict that such assistance will take time in arriving. The CAI designer, however, needs to be aware of this impending shift from text-dominated lessons to graphics-oriented presentations where it will be necessary to design new and different interactions [Siliauskas, 1986, p. 83].

As well, many designers who are currently producing computer based instruction are unaware of the full potentials of animation.

> It seems that many computer based instruction designers do not yet know how to use animation most effectively as it can be seen that its intent may be cosmetic rather than instructional in many cases [Rieber & Hannafin, 1988, p. 77]

There have been a significant number of studies that show that static visuals can have positive effects on learning and attitude when used correctly. However, this same consensus has not yet been reached with animation as there are still too few studies available. In addition, the results of these studies cannot yet be considered reliable as there have been concerns with content and testing validity.

Further research in this area is warranted, and a set of guidelines for the use of animation in computer based instruction should be developed.

CHAPTER III: RESEARCH METHODS

Introduction

This chapter describes the purpose and hypotheses of the study, treatment conditions, subject attributes, assignment of subjects to groups, the data collection process, and how data were analyzed.

The purpose of this study was to examine the effect of computer-displayed animation used in grade ten mathematics computer based instruction. More specifically, this study examined the effect of mathematics computer based instruction lessons using text alone, text and graphics, and text and animation on achievement and attitude of subjects grouped by gender and prior achievement.

To this end, three versions of the same computer based mathematics lesson were prepared. These three different versions of the mathematics lesson became the three treatment conditions for this study. Each subject was randomly assigned by the researcher to one of the three treatments. One treatment used text and computer-displayed animation to deliver instruction. Animation was used to directly illustrate lesson content. The second lesson used computer-displayed stationary graphics and text to deliver instruction. The third version used text only in the instructional process. The typical length of time required to complete any of the above lessons was approximately fifteen minutes.

Hypotheses Examined

It was hypothesized that subjects who used the mathematics lesson with computer-displayed animations and text would score higher on an achievement posttest and have more positive attitudes towards course content than those who used the version that contained computer presented graphics and text. Furthermore, it was hypothesized that subjects who used the mathematics lesson with computer-displayed animation and text would score higher and have more positive attitudes than those who used the version that contained text only. As well, the hypothesis is made that there would be no gender related differences in achievement in the animation treatment group. Finally, it was hypothesized that computer-displayed animation and text to convey content would be a more effective form of display than stationary graphics and text or text alone for both high and low mathematics achievers.

FIGURE 1
Treatment and Gender

Treatment

		1	2	3	
		Text	Graphics	Animation	
Gender	Male	$\bar{X}_{1M}$	$\bar{X}_{2M}$	$\bar{X}_{3M}$	$\bar{X}_{.M}$
	Female	$\bar{X}_{1F}$	$\bar{X}_{2F}$	$\bar{X}_{3I}$	$\bar{X}_{.F}$
		$\bar{X}_{1.}$	$\bar{X}_{2.}$	$\bar{X}_{3.}$	$\bar{X}_{..}$

Treatment 1 (FIGURE 1) uses the version of the computer based mathematics lesson that contains text only. Treatment 2 uses the version of the mathematics lesson that contains static graphics and text to illustrate lesson content. Treatment 3 uses the version of the mathematics lesson that contains computer-displayed animation and text.

The hypotheses that were examined in detail were:

(1) Subjects who receive the treatment that contains computer-displayed animation will obtain higher achievement scores than those who receive the other treatments.

$$Y = \text{achievement},\quad H1{:}(A)\bar{Y}_{3.} > \bar{Y}_{2.} \quad H1{:}(B)\bar{Y}_{3.} > \bar{Y}_{1.}$$

(2) Subjects who receive the treatment that contains computer-displayed animation will have a more positive attitude towards subject matter than those who receive other treatments.

$$y = \text{attitude},\quad H2{:}(A)\bar{Y}_{3.} > \bar{Y}_{2.} \quad H2{:}(B)\bar{Y}_{3.} > \bar{Y}_{1.}$$

(3) The computer based lesson containing animation will have the same effect on posttest achievement for males as it does for females.

$$H3{:}\ \bar{Y}_{3M.} = \bar{Y}_{3F.}$$

(4) Computer-displayed animation will be the most effective form of content display compared to static graphics and text or text alone for both low and high pretest achievers.

FIGURE 2

Treatment and Pretest Achievement Level

		Treatment 1	Treatment 2	Treatment 3	
Pretest Achievement	Low	$\bar{X}_{1L}$	$\bar{X}_{2L}$	$\bar{X}_{3L}$	$\bar{X}_{.Low}$
	High	$\bar{X}_{1H}$	$\bar{X}_{2H}$	$\bar{X}_{3H}$	$\bar{X}_{.High}$
		$\bar{X}_{1.}$	$\bar{X}_{2.}$	$\bar{X}_{3.}$	$\bar{X}_{..}$

$Y =$ achievement, $H4{:}(A)\bar{X}_{3H} > \bar{X}_{2H} > \bar{X}_{1H}$ $\quad H4{:}(B)\bar{X}_{3L} > \bar{X}_{2L} > \bar{X}_{1L}$

Variables

The independent variables for this study are:

(1) Instruction Type; (three levels)
- (a) computer-displayed animation and text.
- (b) computer-displayed graphics and text.
- (c) text alone.

(2) Gender of subject; (two levels)
- (a) male
- (b) female

(3) Pretest achievement; (two levels divided by a median split)
- (a) high
- (b) low

The dependent variables for this study are:

(1) the achievement of each subject as based on his or her score on a paper and pencil written answer and multiple choice test given immediately after the computer based mathematics lesson.

(2) the attitude towards the computer based instruction mathematics lesson based on Likert Scale scores derived from a paper-and-pencil administered attitude survey.

The design attempted to control several variables so as not to confound the results of this study:

(1) Content. All three versions of the mathematics CBI lesson provided the exact same content and feedback for the student. The only variability was in the presentation of the lessons. One version contained animation and text, another contained graphics and text, and the other text only.

(2) Physical Environment. The physical environment of the lab and each individual computer station was kept as consistent as possible throughout the data collection process.

(3) Other variables that could affect results were mitigated through random assignment of subjects.

Subject Data

Undergraduate students from a western canadian university registered in a Bachelor of Education program were used as subjects for this study. Primarily, these students were training to be elementary school teachers. Eight classes (N=173) of students were used as subjects. Of these students, about fifteen percent (N=26) were male and eighty-five percent (N=147) were female. The low number of males who participated in this study can be attributed to the fact that there are a low proportion of males registered in the elementary education undergraduate program at the site university of the study. Although it was known that male enrollment was lower than female enrollment, the number of male participants who actually participated in this study was even lower than anticipated. These students were all registered in a course that taught instruction methods for elementary level mathematics. As a part of their course work, but not for extra credit, they were asked to volunteer for this study. One hundred percent of those asked to volunteer actually participated in the study. Participation in this study was conducted during class time. See APPENDIX 1 for the consent form that was reviewed and signed by each participant in the study. Subjects were made aware that their participation in the study would require approximately one hour of time. Subjects were also informed that the study contained four components; a pretest, an instructional lesson on computer, a posttest, and an attitude survey. Students were not made aware that they would be randomly assigned to one of three different instructional computer lessons.

Treatment Conditions

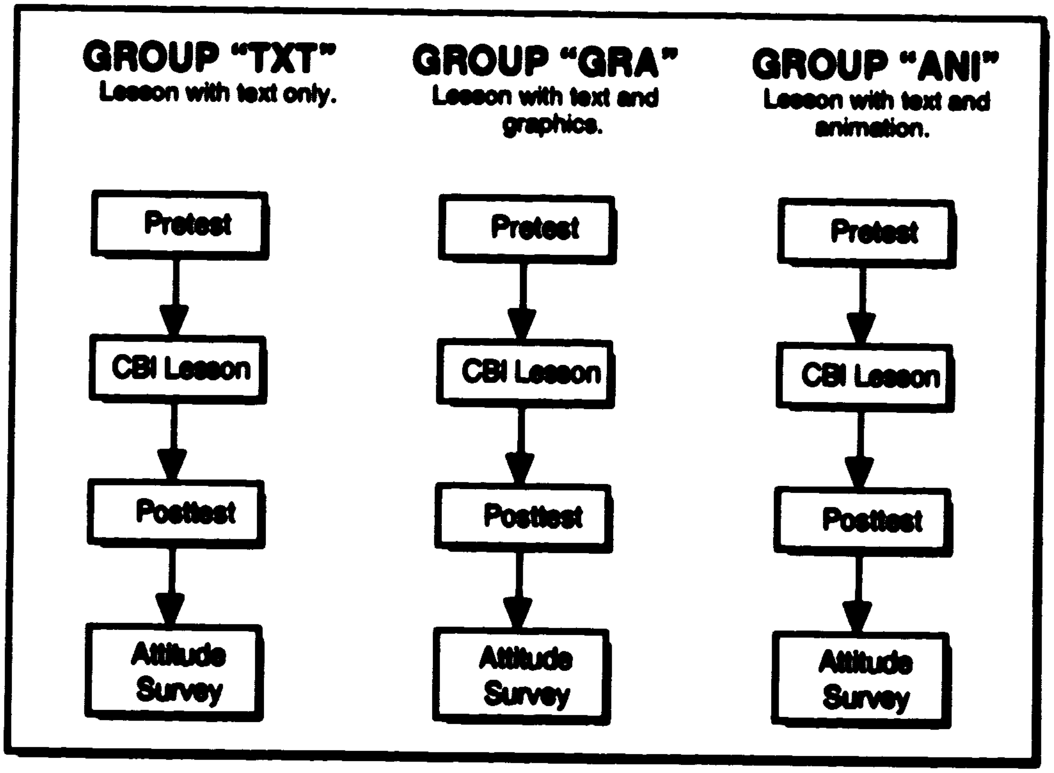
The topic of the mathematics lesson was the construction of triangles. Given three line segments, two line segments and an included angle, or two included angles and one line segment, the student was charged with constructing the resultant triangle from the given data using only a compass, straightedge, and pencil.

Subjects were randomly assigned by the researcher into one of three groups. Each subject was handed a closed paper packet that contained their posttest and attitude survey with instructions not to open it. On the back of this packet was a three digit identification number. Upon signon to the computer mathematics program, students were asked by the computer for this identification number. Subjects who received a packet that had a identification number with one as a prefix were automatically routed by the computer into treatment group one, the lesson that contained text only. Subjects who received a packet that had an identification number with two as a prefix were similarly put into group two, the static graphics lesson, and those with three as a prefix received treatment three, the computer-displayed animation group. The researcher was blind to which identification number a subject received as it was located out of view on the back of the paper package.

A description of the three treatment conditions is as follows:

FIGURE 3

Research Design



(1) One group, named ANI, received the version of the mathematics lesson that contained computer-displayed animations and text. Animations were used to directly illustrate lesson content. A process was shown on the screen which involved a compass and the given lines. The compass moved throughout the screen, performing various measurements and drawing corresponding arcs.

(2) The second group, named GRA, received the version of the mathematics lesson that contained computer-displayed graphics and text. The static graphics used in this lesson were derived from single key

frames from each animation contained within the lesson. No additional graphics were added or developed other than the single frames taken from each animation.

(3) The final group, named TXT, received the version of the lesson that contained text only. The text in this lesson was enhanced to account for the missing graphics and animations.

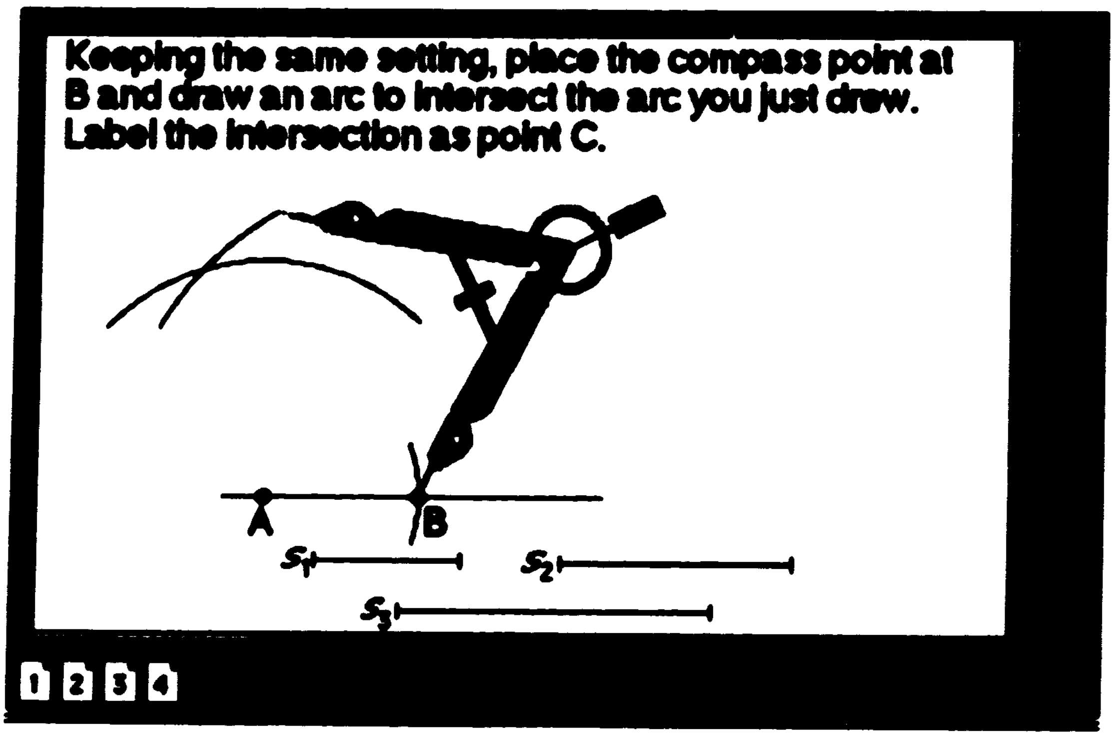
Instructional Content

The lesson used for this study was taken from a computer based instruction package called Math 13 CBI. Math 13 is the equivalent of the non-academic track of the grade ten high school mathematics curriculum in a western canadian province. See APPENDIX 2 for the permission letter that allowed the use of these CBI materials in this study. Taking all lessons in the entire Math 13 CBI package into account, the total amount of instruction delivered via computer is equal to approximately one hundred twenty hours. This instruction package was developed by a county school district for the Provincial Department of Education and the Provincial Distance Learning Centre. The courseware was completed in 1992 and has since then gone through extensive alpha and beta testing in five county high schools. Nearly three hundred students have completed Math 13 in these schools using the computer based instruction package. As well, the Provincial Distance Learning Centre conducted a curriculum validity review of the materials in conjunction with mathematics teachers throughout the province. The computer based package was approved for province wide beta release in September of 1992.

The original Math 13 CBI lesson that this study uses contained computer-displayed animation and text. A second lesson, using static graphics and text was derived from the original lesson. For example, in the process of drawing a triangle when given three sides, the animated lesson shows the compass moving around the screen and "drawing" arcs. For the static graphic lesson, five or six of the key frames from the animated lesson that depicted the correct steps were captured and then used alone instead of the animation. An example of one of the static graphic screens is shown in FIGURE 4.

FIGURE 4

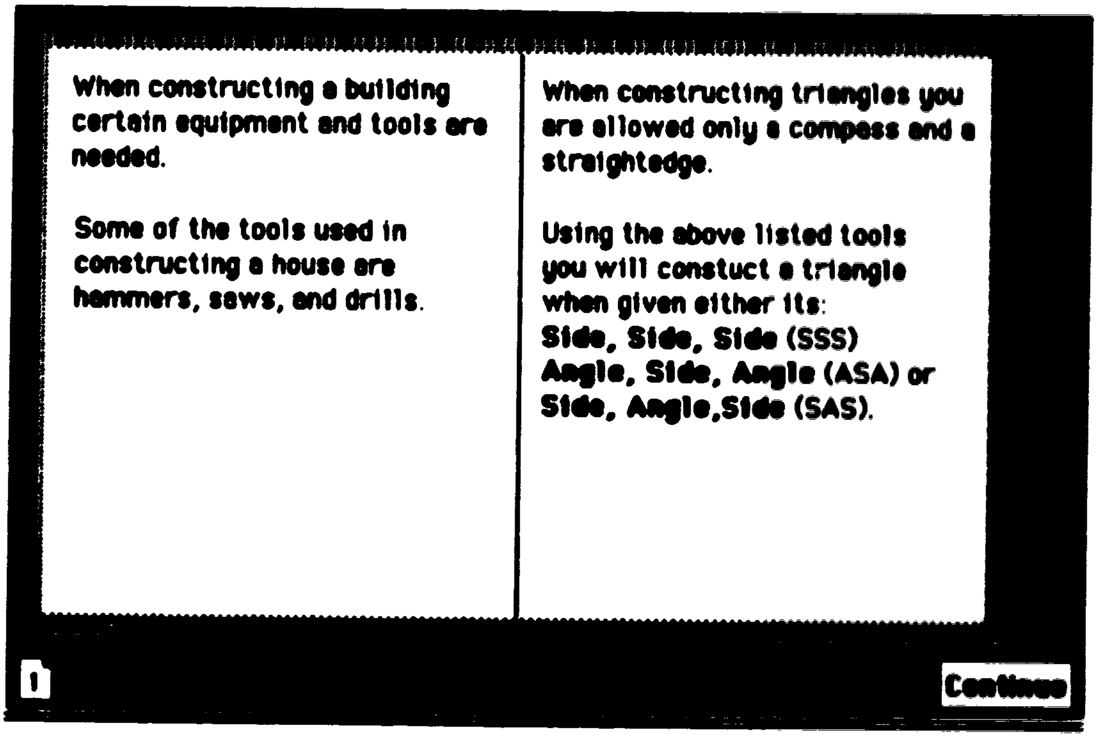
Sample CBI Graphic Screen



For the text only lesson, all graphics and animations were removed. Text was the only means in which lesson content was conveyed. Since the graphic and animation versions of the CBI lesson used a minimal amount of text, the text for the textual based lesson had to be enhanced in order to account for the loss of information that occurred when graphic images were removed. An example of a text only screen is shown in FIGURE 5.

FIGURE 5

Sample CBI Text Screen



The individual who led the Math 13 CBI development team, assisted in the development to ensure quality and continuity of all three versions of the lesson. Besides practical experience in developing CBI, he is an experienced mathematics teacher.

Courseware was developed for use on the Macintosh computer. All lessons were developed in black and white only as this software package was originally designed for use with inexpensive Macintosh computers that are not capable of displaying color. In a school setting, the entire package is accessed through a server over a networked computer lab. The courseware cannot practically be stored on each individual machine as the entire package requires nearly forty megabytes of disk space. The authoring system that was used to create the lessons and the student management system is Authorware Professional Version 1.7.1. Animations added to the mathematics lesson for the purpose of this study were created using a combination of three pieces of software. SuperPaint 3.0, a graphics development program, Macromind Director 3.1, an animation package, and Authorware Professional 1.7.1, which has some inherent animation features, were used.

Research Design

See FIGURE 3 to review the research design of this study. All subjects for this study received the same pretest, attitude survey, and posttest. The only difference in treatments was the version of the computer based mathematics lesson that was used. The study was conducted in the main computer lab in the Education Building for the Faculty of Education. The mathematics software was installed on the hard drives of twenty-five workstations in the lab. Each workstation consisted of a Macintosh IIci or Macintosh Centris 610 computer, a fourteen inch color RGB display, an Apple extended keyboard, and an Apple Desktop Bus Mouse pointing device. Workstations were located in carrels beside each other in five rows of five. Sixty centimetre vertical dividers separated each workstation.

Subjects were grouped by sex and then randomly assigned to one of the three treatment groups by the researcher as described earlier. Instructional content was delivered solely by the computer based lesson.

A short computer delivered tutorial sequence was given at the beginning of the lesson describing use of the built in navigation controls supplied for the subject to move through the lesson. The researcher answered question ·'ated only to the use of these navigational controls. Subjects were allowed to proceed through the lesson at their own pace. Using navigation controls during the lesson, the subject was able to repeat any part of the lesson at any time. However, once the student finished the lesson and entered testing mode, the lesson material was unavailable.

Data Collection

Pretest data for each subject was collected by the computer and written to an individual file for each subject on the network server. The pretest consisted of nineteen questions in free text entry format. See APPENDIX 3 for a list of the questions that were used. The subject was given one chance to answer the question. One point was given for a correct answer; no points were given for an incorrect answer. Scores for each individual question were collected and stored for each student. Total score for the pretest was calculated for each subject and also written to their data file.

After the pretest, the subject began the computer based instruction lesson. See APPENDIX 4 for copies of the three versions of the CBI lessons that were used in this study. Subjects were given as much time as needed to complete the lesson.

The posttest was a paper based examination, see APPENDIX 5. A paper based examination was chosen to assess post lesson proficiency. A geometry set was provided for each student to use on the test. The posttest consisted of six long answer and two multiple choice questions for a possible total score of thirty-three points. The long answer questions were worth four to six marks each as there were four to six steps required to reach a correct answer. One mark was awarded for each step of the problem that was completed correctly. Questions were derived from the original Math 13 CBI materials. Total score for the posttest was manually graded and recorded for each subject and added to their electronic data file.

The attitude survey was the last component of the study and was also paper administered since it immediately followed the paper based posttest. A copy of the attitude survey is included in APPENDIX 6. It consisted of twenty-five questions. Subjects were asked to respond to these questions using a five point Likert Scale providing responses ranging from strongly agree to strongly disagree. The test was originally developed as a measurement of attitude toward computer assisted instruction at Penn State University over fifteen years ago. The test was further modified to reflect attitude regarding mathematics based computer assisted instruction in 1987 at a western canadian university [Forsyth, 1991]. The survey tested for attitude levels towards a number of sub-topics. For example, the survey measured student levels of motivation towards the lesson. As well, the survey endeavored to measure the comfort level, or how at ease each subject felt using the CBI lesson. Technical and operational difficulties that subjects possibly encountered were also addressed. Furthermore, subjects were queried as to the amount of lesson flexibility and freedom of pace they experienced. Scores for the attitude survey were manually calculated and were again added to each subject's data file.

Only after the attitude survey was completed were the subjects given the opportunity to view their scores on the pretest and posttest. This was done as subject knowledge of pretest score prior to completing the remaining treatment components could unduly influence response to those components.

Data Analysis

To establish the reliability of the data collection instruments, a reliability analysis of the pretest, posttest, and attitude survey were conducted. As well, an analysis of variance of the pretest scores across the three treatment groups was conducted. No significant difference of pretest scores of the three groups should exist as subjects were randomly assigned to treatments.

To test the first hypothesis regarding achievement of subjects in the animation treatment group in relation to other treatments, a one-way analysis of variance of posttest scores between the three groups was conducted. Means and standard deviations of each group were examined. The follow up test was Scheffé's *t*-test of significance to establish if the differences between any pairs of means were significant ($p \leq .05$). The same approach was used to analyze the attitude data.

To test the third hypothesis regarding the achievement scores of subjects in the animation treatment grouped by gender, a t-test was conducted to examine if the difference between the means of the two groups were significant. The means and standard deviations of the two gender groups were also examined.

To test the fourth hypothesis regarding the most effective form of content display for subjects of low and high prior mathematics ability, a number of steps were undertaken. First, the median score for the pretest was established to group subjects within each treatment as either high pretest achievement or low pretest achievement. Following that, a one-way analysis of variance was conducted on the posttest scores of the low pretest achievers across the three treatment groups. The same process was conducted on the posttest scores of the subjects who were categorized as having a high pretest score. Post-hoc Scheffé tests were conducted accordingly. The results of the above mentioned statistical tests can be found in the following chapter.

CHAPTER IV: RESULTS

Introduction

This chapter presents the findings of this study. First, reliability of the measurement instruments; the pretest, posttest, and attitude survey, are established. Next, statistical analysis relating to each hypothesis are presented. For this research study, any statistic with a probability of occurrence above 95% ($p \leq .05$) was deemed significant.

Subject Data

Detailed demographic information for each subject was neither collected or required for the type of analysis conducted in this study. All subjects were adults aged eighteen and over. A total of one hundred seventy-seven subjects participated in this study. Of this number, two subjects did not complete their specified treatment because of technical difficulties with the computer hardware. As well, two subjects made the decision to opt out of their treatment during data collection. This brought the total number of subjects who completed participation in the study to one hundred seventy-three. Of this final number, twenty-six were male and one hundred forty-seven were female.

Reliability

The question of reliability of data collection instruments must be addressed because of the quantitative nature of this study and the type of statistical analysis that was subsequently conducted. This section will establish the reliability of the pretest, posttest, and attitude survey.

Pretest

The pretest used for this study was nineteen items in length. It was computer-delivered and was free-response answer based. It covered general geometry and other assorted mathematics questions. All questions were taken directly from the Math 13 computer based instruction modules, which is based on approved curriculum. These questions have been used and tested by hundreds of students who have successfully completed the Math 13 course using computer based instruction. Furthermore, the test was developed with the assistance of a content expert. This expert, who supervised the development of the Math 13 computer based instruction package and is a certified mathematics teacher.

One mark was awarded to a subject for a correct answer, and no marks were awarded for an incorrect answer. The total number of marks possible for the pretest was nineteen.

An item-by-item reliability analysis was conducted of the pretest scores collected using Cronbach's coefficient alpha test with a follow-up application of the Spearman-Brown prophecy formula. The results of the reliability test are found in TABLE 1.

TABLE 1

Pretest Reliability Analysis - Scale (Alpha)

Pretest Items		Mean	Std Dev	Cases
1.	ITEM 01	.69	.46	173.0
2.	ITEM 02	.79	.41	173.0
3.	ITEM 03	.80	.40	173.0
4.	ITEM 04	.15	.36	173.0
5.	ITEM 05	.84	.36	173.0
6.	ITEM 06	.47	.50	173.0
7.	ITEM 07	.58	.50	173.0
8.	ITEM 08	.97	.17	173.0
9.	ITEM 09	.29	.46	173.0
10.	ITEM 10	.32	.47	173.0
11.	ITEM 11	.18	.38	173.0
12.	ITEM 12	.51	.50	173.0
13.	ITEM 13	.79	.41	173.0
14.	ITEM 14	.84	.36	173.0
15.	ITEM 15	.76	.43	173.0
16.	ITEM 16	.27	.45	173.0
17.	ITEM 17	.87	.33	173.0
18.	ITEM 18	.71	.46	173.0
19.	ITEM 19	.24	.43	173.0

N of Cases = 173.0

Reliability Coefficient 19 items Alpha = .63

Cronbach's Coefficient Alpha test of reliability uses a split half method that may yield low reliability scores for testing instruments that are of shorter length. Because of the short length of the pretest (nineteen items), the Spearman-Brown Prophecy Formula was applied. The Spearman-Brown Prophecy Formula is a statistic that estimates test reliability if the test was of identical composition but twice the length. Using Spearman-Brown, the pretest had an adjusted reliability of 0.77. This value would categorize the pretest as reliable.

Posttest

The posttest was paper-and-pencil based. It consisted of six multiple-step free response problems and two multiple choice problems. For the multiple step questions one mark was awarded for each step that was completed properly. Problem one consisted of four possible marks, problem two consisted of five marks, problem three consisted of four marks, problem four consisted of six marks, problem five consisted of six marks, and problem six consisted of five possible marks. Of the two multiple choice questions, the first had one mark to be awarded for a correct answer and the second had two marks to be awarded for a correct answer. The total number of possible marks available for the posttest was thirty-three.

All posttest questions were taken directly from the Math 13 computer based instruction modules. These questions have been used by the hundreds of students who have successfully completed the Math 13 course using computer based instruction. The Math 13 questions are based upon approved curriculum. The posttest was developed with the assistance of a content expert.

An item-by-item reliability analysis was conducted of the posttest scores collected using Cronbach's coefficient alpha test. The results of this reliability test are found in TABLE 2.

TABLE 2

Posttest Reliability Analysis - Scale (Alpha)

Posttest Items		Mean	Std Dev	Cases
1.	ITEM 1	2.55	1.60	173.0
2.	ITEM 2	2.00	1.97	173.0
3.	ITEM 3	1.64	1.66	173.0
4.	ITEM 4	1.77	2.30	173.0
5.	ITEM 5	.62	1.45	173.0
6.	ITEM 6	1.69	2.13	173.0
7.	ITEM 7	.89	.31	173.0
8.	ITEM 8	.97	1.00	173.0
	N of Cases =	173.0		

Reliability Coefficient 8 items Alpha = .83

An alpha level of 0.83 would categorize the posttest as a reliable data collection instrument.

Attitude Survey

The attitude survey was paper-and-pencil based and immediately followed the posttest. It consisted of twenty-five Likert scale attitude questions.

An item by item reliability analysis was conducted of the attitude survey scores collected using Cronbach's coefficient alpha test. The results of this reliability test are found in TABLE 3.

TABLE 3

Attitude Survey Reliability Analysis - Scale (Alpha)

Survey Item		Mean	Std Dev	Cases
1.	ITEM 01	3.42	1.13	173.0
2.	ITEM 02	2.94	1.14	173.0
3.	ITEM 03	3.45	1.08	173.0
4.	ITEM 04	2.99	1.04	173.0
5.	ITEM 05	3.51	.99	173.0
6.	ITEM 06	3.49	1.13	173.0
7.	ITEM 07	3.34	1.12	173.0
8.	ITEM 08	3.03	1.21	173.0
9.	ITEM 09	3.03	1.07	173.0
10.	ITEM 10	3.23	1.14	173.0
11.	ITEM 11	2.61	.90	173.0
12.	ITEM 12	2.73	1.01	173.0
13.	ITEM 13	2.50	1.03	173.0
14.	ITEM 14	2.70	.97	173.0
15.	ITEM 15	2.34	1.07	173.0
16.	ITEM 16	3.01	1.13	173.0
17.	ITEM 17	2.09	.92	173.0
18.	ITEM 18	2.77	1.10	173.0
19.	ITEM 19	3.27	1.08	173.0
20.	ITEM 20	3.38	.98	173.0
21.	ITEM 21	3.54	.91	173.0
22.	ITEM 22	2.75	1.05	173.0
23.	ITEM 23	3.73	.69	173.0
24.	ITEM 24	3.14	.98	173.0
25.	ITEM 25	4.17	.91	173.0

N of Cases = 173.0

Reliability Coefficient 25 items Alpha = .86

An alpha level of 0.86 would categorize the attitude survey as a reliable test.

Random Assignment

Subjects were randomly assigned by the researcher to one of the three treatments. Through random assignment, it is assumed that there will be equal distribution of ability across all three groups. To test the assumed equal distribution of ability to the treatment groups, an analysis of variance of the pretest scores was conducted to examine for significant differences between groups. There should be no significant difference in the pretest scores of the three groups. The results of this test are shown in TABLE 4.

TABLE 4

Analysis of Variance - Pretest Scores

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN+RESIDUAL	1411.59	170	8.30		
TRMT	24.11	2	12.06	1.45	.237
(Model)	24.11	2	12.06	1.45	.237
(Total)	1435.70	172	8.35		
R-Squared =	.02				
Adjusted R-Squared =	.01				

The analysis of variance returned an F value of 1.45 with a significance level of .237. The result of this test confirms that there was no significant difference in the pretest scores of the three different groups and supports the hypothesis of group equivalence.

Hypothesis One - Achievement

Hypothesis One predicted that the subjects who received the treatment with computer-displayed animation would score higher on an achievement posttest than those who received other treatments.

A one-way analysis of variance was conducted on posttest scores using treatment as a factor to examine if significant differences between the mean posttest scores of each treatment existed. These results are found in TABLE 5.

TABLE 5

Analysis of Variance - Posttest Achievement Scores

Variable POSTTEST SCORE
By Variable TREATMENT

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	3890.73	1945.36	32.34	.00
Within Groups	170	10226.66	60.16		
Total	172	14117.39			

The analysis of variance yielded an F value of 32.34 which was statistically significant. An examination of sub-population posttest means and standard deviations was then conducted. These descriptions are found in TABLE 6.

TABLE 6

Summary of Posttest Mean Scores

Treatment	Mean	Std Dev	Cases
Text	6.88	5.80	59
Graphics	11.35	8.10	57
Animation	18.39	9.07	57
For Entire Population	12.15	9.06	173

The text treatment group had the lowest mean posttest score. The graphics treatment group attained a higher mean posttest score than the text group. The mean posttest score for the computer-displayed animation treatment group was the highest. Scheffé's t-test was performed to analyze whether the differences between these groups was statistically significant. The result of this test is found in TABLE 7.

TABLE 7

Scheffé Test of Significance - Posttest Achievement Scores

Mean	Label		TRMT 1 2 3
6.88	Text	TRMT 1	
11.35	Graphics	TRMT 2	*
18.39	Animation	TRMT 3	* *

(*) Indicates significant differences which are shown in the lower triangle

The Scheffé test showed the differences to be significant. These findings are consistent with both parts of Hypothesis One that predicted the computer-displayed animation treatment group to score higher on the achievement posttest than those who received the stationary graphics treatment and the text treatment.

Hypothesis Two - Attitude

Hypothesis Two predicted that the subjects who received the treatment with computer-displayed animation would score higher on the post lesson attitude survey than those who received other treatments.

A one-way analysis of variance was conducted on attitude scores using treatment as a factor to examine if significant differences between the mean attitude survey scores of each treatment group existed. These results are found in TABLE 8.

TABLE 8

Analysis of Variance - Attitude Survey Scores

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	1	550.12	550.12	6.93	.01
Within Groups	171	13567.27	79.34		
Total	172	14117.38			

The analysis of variance test returned an F value of 6.93 which was statistically significant. Based on this test, a description of sub-population means and standard deviations of attitude survey scores was warranted. This description is found in TABLE 9.

TABLE 9

Summary of Attitude Survey Mean Scores

Treatment	Mean	Std Dev	Cases
Text	72.47	13.07	59
Graphics	79.40	11.48	57
Animation	79.75	11.00	57
For Entire Population	77.16	12.30	173

The text treatment group had the lowest mean in attitude survey score. The graphics treatment group and the animation treatment attained nearly identical scores.

Follow up Scheffé *t*-tests were performed to analyze whether the difference between groups was statistically significant. These analyses can be found in TABLE 10.

TABLE 10

Scheffé Test of Significance - Attitude Survey Scores

Mean	Label		TRMT 1 2 3
72.47	Text	TRMT 1	
79.40	Graphics	TRMT 2	*
79.75	Animation	TRMT 3	*

(*) Indicates significant differences which are shown in the lower triangle

Both the animation and graphics treatment groups scored significantly higher than the text treatment group. The difference between the animation and graphics treatment groups was not found to be significant. This result supports Hypothesis Two (B) that stated the animation group would attain higher attitude scores than the text group but refutes the Hypothesis Two (A) that stated that the animation group would attain higher attitude scores than the graphics group.

Hypothesis Three - Achievement Grouped by Gender Within Animation Treatment Group

Hypothesis Three examined if there was a gender difference in achievement score within the animation treatment group. A *t*-test was conducted on the mean posttest scores of males and females in the treatment group that used computer-displayed animation in the mathematics CBI lesson. The results of this analysis are found in TABLE 11.

TABLE 11

T-Test of Posttest Achievement Score - Subjects Grouped by Gender Within Animation Treatment

Variable	Number of Cases	Mean	SD	SE of Mean
Male	8	20.75	9.44	3.34
Female	49	18.00	9.05	1.30

Mean Difference = 2.7500

Levene's Test for Equality of Variances: F= .062 P= .804

The difference between scores of males and females was not found to be significant. However, no matter what outcome this test may have yielded, the result may not be accurate because of the low number of males (N=8) in the animation treatment group.

Hypothesis Four - Posttest Achievement of Low and High Level Pretest Achievers

Hypothesis Four stated there would be an interaction between treatment and pretest achievement score. For this analysis, subjects were grouped by either high or low pretest achievement score. It was found that the median score for the pretest was eleven marks out of the possible nineteen. These results are found in TABLE 12.

TABLE 12
Median Pretest Score Analysis

(19 possible marks)

Score	Frequency	Percent	Valid Percent	Cum Percent
1	1	.6	.6	.6
4	1	.6	.6	1.2
5	4	2.3	2.3	3.5
6	5	2.9	2.9	6.4
7	3	1.7	1.7	8.1
8	15	8.7	8.7	16.8
9	21	12.1	12.1	28.9
10	24	13.9	13.9	42.8
11	23	13.3	13.3	56.1
12	23	13.3	13.3	69.4
13	14	8.1	8.1	77.5
14	21	12.1	12.1	89.6
15	5	2.9	2.9	92.5
16	8	4.6	4.6	97.1
17	5	2.9	2.9	100.0
Total	173	100.0	100.0	

Median 11.000 Std dev 2.89

Percentile	Value	Percentile	Value	Percentile	Value
25.00	9.00	50.00	11.00	75.00	13.00

Valid cases 173 Missing cases 0

Based on this description, subjects in each group were then classified as low pretest score or high pretest score. Subjects who scored less than eleven on the pretest were categorized as low achievement. Subjects who scored higher than eleven were categorized as high achievement. All twenty-three subjects who attained a median score of 11 were discounted for this analysis.

The posttest scores of the low pretest achievers were examined first. A one way analysis of variance on posttest scores of low pretest achievers across the three treatments was conducted. These results are found in TABLE 13. To re-examine how subjects were grouped for this analysis, see FIGURE 2.

TABLE 13

Analysis of Variance - Posttest Achievement Scores for Low Pretest Achievers

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	1251.55	625.77	10.90	.00
Within Groups	70	4018.34	57.40		
Total	72	5269.89			

TABLE 13 shows that there was a significant difference between posttest scores of low achievement subjects across the three treatments ($p \leq .05$). This result warranted further examination of these scores. A description of means and standard deviations is found in TABLE 14.

TABLE 14

Summary of Posttest Achievement Mean Scores of Low Pretest Achievers

Treatment	Mean	Std Dev	Cases
Text	4.95	3.72	20
Graphics	8.48	7.35	28
Animation	15.12	9.70	26
For Entire Sub-Population	9.74	8.57	74

A post-hoc Scheffé test was then conducted to examine if these differences in score are significant. The results of this test can be found in TABLE 15.

TABLE 15

Scheffé Test of Significance - Achievement Posttest Scores of Low Pretest Achievers

Mean		1 2 3
4.95	TRMT 1	
8.48	TRMT 2	
15.12	TRMT 3	* *

(*) Indicates significant differences which are shown in the lower triangle

The Scheffé test reveals that greater posttest score achieved by subjects in the animation treatment is significantly higher than the other two treatment groups which supports the first part of the fourth hypothesis. To analyze the validity of the second part of the fourth hypothesis, a similar analysis of posttest results of the high pretest achievers was needed. The results of an analysis of variance of posttest scores for high pretest achievers can be found in TABLE 16.

TABLE 16

Analysis of Variance - Posttest Achievement Scores for High Pretest Achievers

Source	D.F.	Sum of Squares	Mean Squares	F Ratio	F Prob.
Between Groups	2	2361.47	1180.74	20.23	.00
Within Groups	73	4259.95	58.36		
Total	75	6621.42			

TABLE 16 shows that there was a significant difference between posttest scores of subjects across the three treatments ($p \leq .00$). This result required a further examination of these scores to be made. A description of means and standard deviations is found in TABLE 17.

TABLE 17

Summary of Achievement Posttest Mean Scores - High Pretest Achievers

Treatment	Mean	Std Dev	Cases
Text	8.57	6.94	30
Graphics	15.57	8.27	21
Animation	21.68	7.89	25
For Entire Sub-Population	14.82	9.40	76

High pretest achievers who received the treatment with computer-displayed animation attained the highest scores on the posttest in relation to other high pretest achievers who received other treatments. High achievers who received the treatment with static graphics in the CBI lesson scored second highest on the posttest, and the text only treatment group scored lowest compared to other subjects who scored well on the pretest. A post-hoc Scheffé test was then conducted to examine if these differences in score are significant. The results of this test can be found in TABLE 18.

TABLE 18

Scheffé Test of Significance - Posttest Achievement Scores of High Pretest Achievers

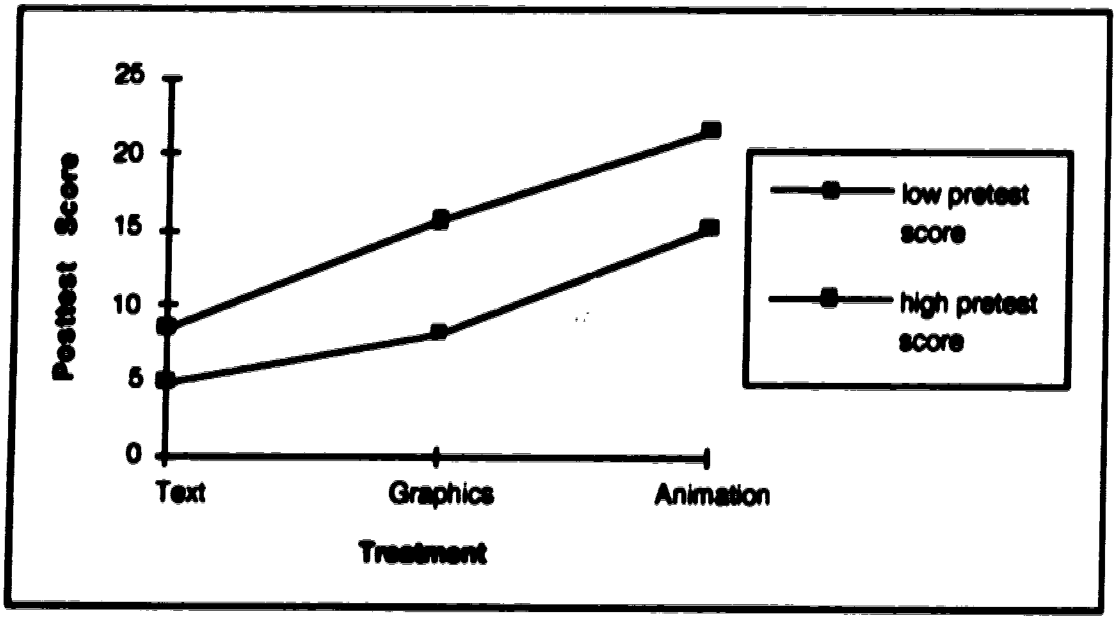
Mean		1	2	3
8.57	TRMT 1			
15.57	TRMT 2	*		
21.68	TRMT 3	*	*	

(*) Indicates significant differences which are shown in the lower triangle

The Scheffé test reveals that greater posttest score achieved by subjects in the animation treatment is significantly higher than the other two treatment groups which supports the second part of the fourth hypothesis. Based on the data collected from this research, and the subsequent statistical analysis, both parts of the fourth hypothesis are supported.

A graphical summary of the posttest scores of both high and low pretest achievers across all the treatments is presented in FIGURE 6.

FIGURE 6
Posttest Achievement Performance Summary



Summary

In summary, the results of this study show that computer-displayed animation used in mathematics CBI is an effective form of media that positively affects achievement and attitude. Subjects who received the treatment that contained animation scored significantly higher than those subjects who received the other two treatments. As well, subjects who received the treatment that contained computer-displayed animation scored significantly higher than those subjects who received the text only treatment on the attitude survey. The members of the animation group did not score significantly higher on the attitude survey than subjects who were in the static graphics treatment group.

It was also found that the scores of males and females in the computer-displayed animation treatment group was not significantly different. However, this finding is invalid because of the lower than expected number of males in proportion to females in the animation treatment group.

Finally, the hypothesis that computer-displayed animation would be the most effective display medium in terms of resultant posttest scores for both high and low pretest achievers was supported.

Discussion of the results relating to hypotheses, implications of computer-displayed animation in CBI, and recommendations for further research based on these results can be found in the next chapter.

CHAPTER V: SUMMARY AND DISCUSSION

Summary

The purpose of this study was to examine the effect of mathematics computer based instruction lessons using text alone, text and graphics, and text and animation on achievement and attitude of subjects grouped by gender and prior achievement. Discussion will be presented relating to each hypothesis made and will be based on the results of the data analysis of the previous chapter. The implications of animation on computer based instruction will also be discussed along with recommendations that can be made for further research in this area.

Discussions

Hypothesis One

The first hypothesis stated that subjects who received the treatment that used the CBI lesson with computer-displayed animation would achieve higher posttest scores than those subjects who received the other treatments. The animation treatment group outscored the graphics treatment group by 21.3%. The animation treatment group also outscored the text only treatment group by 34.8%. These differences are significant.

Based on these results, computer-displayed animation yielded a positive effect on posttest achievement compared to other forms of display. This finding is consistent with Mayton [1991], Baek & Layne [1988], and Rieber [1991].

Rieber & Kini [1991, p. 86] report that "there are times when visuals can facilitate learning, times when visuals do not aid learning but do no harm, and times where visuals can be detrimental to learning due to distraction." Based on the results of this study, the animated visuals in the animated CBI lesson appear to have been used properly to facilitate learning. As well, it appears that the computer-displayed animation was superior to still graphics and text and text alone in aiding subjects to immediately recall rules and relationships conveyed in the computer based lesson.

Rieber & Kini also recommend that the use of animation should be dictated by the needs of the learner and the demands of the learning task. Based on the results of this study, it seems clear that for this particular circumstance, animation best suited the learning task at hand. That is not to say that text alone cannot be effective in CBI. Many early CBI applications were predominately text only or text with some graphics. The research of that time still found that CBI exerted positive effects on the learner's achievement. This point seems to emphasize that the instructional designer must be sure that computer-displayed animation is relevant to the learning objective of the lesson.

Hypothesis Two

The second hypothesis stated that subjects who received the treatment that used the CBI lesson with computer-displayed animation would achieve higher attitude survey scores than those subjects who received the other treatments. The attitude scores for all three treatment groups was moderately high with an overall mean of 77.16 points out of a total of 125 possible points. The animation treatment group outscored the graphics treatment group by 0.3%. The animation treatment group also outscored the text treatment group by 5.8%. The difference between the animation treatment and the text treatment is significant, however, the difference between the animation and graphics treatments is not significant. This raises the question of why there was a lack of difference in score between the ANI and GRA treatments. Three hypotheses for this result seem plausible.

One possibility is that subjects approve of *both* graphics and animation as a part of computer based instruction lessons and comparatively do not approve of text alone as a means of instruction.

Another possibility for this finding is that aesthetically, the static graphic and computer-displayed animation versions of the CBI lesson are virtually identical, hence the lack of difference in attitude scores between those two groups. The static graphics were single frames taken from the animations in the other lesson. If attitude was influenced by aesthetics, this could account for the lack of difference in score between those two groups.

There is a third possibility for this result. The only difference between the lessons was the visual form in which content was displayed. The computer graphics lesson used stationary images and text to convey content. The computer-displayed animation treatment using moving pictures or objects in animation, and text to convey content. Animation or movement of visual images alone might not be a factor of attitude which would account for this result, although animation did clearly affect posttest achievement.

As well, there is another factor to consider. The computer-displayed animation and stationary graphics used in the CBI lessons were used to directly convey lesson content. Rieber [1990] has noted that animation can be used for purposes other than delivery of content. For example, it can also be used as a non-content related motivational device, or in user feedback. Animation or graphics used in these circumstances may affect attitude scores.

Based on the results of this study, there is a larger positive effect of graphic or animated visual images in a computer based instruction lesson on attitude of the learner, than CBI lessons that do not contain any visual images.

Hypothesis Three

Hypothesis three stated that there would be no difference in posttest achievement for males and females within the animation treatment group. Although the research of Lee [1991] and Burns & Bozeman [1981] has shown an inclination for males to achieve higher than females in mathematics as a result of computer based instruction, it was hypothesized that computer-displayed animation was a medium that could exert an equally positive effect for both genders.

TABLE 11 shows that males in the animation treatment group outscored females by 8.3%. A *t*-test revealed this difference not to be significant. As well, there were only 8 males in a total treatment size of 57 subjects. This means that no matter what result the *t*-test may have yielded, the low number of males in proportion to females within the animation treatment group could render those findings invalid. Because of this fact, more research in this area is warranted.

Hypothesis Four

Hypothesis four stated that computer-displayed animation and text will be the most effective form of display to convey content compared to static graphics and text or text alone for both low and high pretest achievers. For subjects who achieved a low pretest score, the most effective method of display was computer-displayed animation and text. The second most effective display was stationary graphics and text. The least effective form of display of lesson content was text alone. The same trend was true for subjects who attained high pretest achievement scores.

This hypothesis was really a follow up to hypothesis one. It showed that not only was computer-displayed animation the most effective form of display overall, it was also the most effective for both low achievers and high achievers. This is significant as these results show that animation can be of benefit to any level of learner, not just one particular level of achievers over another.

Implications of Animation for Computer Based Instruction

Based on the results of this study, it is recommended that computer-displayed animation be incorporated into mathematics computer based instruction to convey content in lessons that contain a psychomotor component and visual testing. Doing so would be consistent with these findings and would indicate that the achievement of students who use CBI with computer-displayed animation will be benefited. As well, the findings of this study would also indicate the students would have a positive attitude towards the CBI lesson itself if computer-displayed animation is used.

Recommendations for Further Research

Based on the outcomes of this research, and a sample of literature currently available in this field of study, there are six recommended areas for further research in this area .

First, research of this type should be replicated with different age groups and different subject areas. Little research has been done to date regarding animation, yet end users and developers of computer based instruction alike may find this information to be important. A large research base of positive results needs to be developed before computer-displayed animation should be accepted as an acceptable medium to convey content in a computer based instruction lesson.

Second, research should be conducted comparing how subjects of different gender learn when using computer-displayed animation in CBI. This study attempted to examine this question, but because of a low number of males, statistically significant results could not be achieved. The results of this research may be required by educators and CBI developers alike who will be faced with more computer based instructional resources in the future.

Third, research should be conducted crossing computer-displayed animation with other aspects of computer based instruction. This study, along with others currently available like Mayton [1991] and Rieber [1990] have shown the positive effect that computer-displayed animation can have for the learner. Research should be conducted that would cross this positive learning tool with other aspects of computer assisted instruction. Use of computer-displayed animation as a motivational device, use of animation in learner feedback, and use of animation with color are three examples of this. Along these same lines, it would be interesting to cross computer-displayed animation with non-CBI forms of instruction such as visualization techniques.

Fourth, research should be conducted that tests the effects of varying levels of user control of animation on achievement and attitude. The ability to start, stop, pause, play forward, play backward, and play at various speeds could significantly affect learning outcomes as measured by achievement and attitude [e.g. Worthington, 1993]. As well, repetition of animation as well as viewing animation from different dimensional perspectives should be examined. If animation is established as an effective form of display, studies of this nature would show how it could be used most effectively.

Fifth, the retention of content by the learner who uses a computer based lesson with computer-displayed animation should be studied. This study examined retention directly after a CBI lesson was completed. The ability of the subject to retain content over a period of time as a result of computer-displayed animation is a valid area of research that should be examined.

Finally, the research should be replicated with achievement tests having more items so as to elevate criterion test reliability data.

Conclusion

This study found that computer-displayed animation used in a computer based instruction lesson has positive effects on achievement and attitude.

Subjects that received the lesson with computer-displayed animation scored significantly higher on the achievement posttest than those who received the treatment with graphics and text and those who received the treatment with text alone and this effect size was large and proven to be statistically significant. The subjects that received the treatment with computer-displayed animation scored significantly higher on the attitude survey than those subjects who received the computer based lesson with text alone. The computer-displayed animation treatment group did not score significantly higher than the computer-displayed graphics group on the attitude survey.

This study also found that there was no difference in effect of computer-displayed animation on males compared to females, but this result was not found to be valid because of an unanticipated low number of males in the treatment group. More research should be conducted in this area.

This study also found that computer-displayed animation was the most effective form of display compared to stationary graphics for both high prior achievers and low prior achievers.

From a review of the few studies examining computer-displayed animation, and the results of this research study, it is clear that more research needs to be conducted in this area. Once researchers establish if computer-displayed animation is an effective form of display for content in computer based instruction lessons, further research needs to be conducted that will establish specific proper guidelines for its use.

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Appendix 1

Subject Consent Form

Subject Consent Form

Researcher: Brent Poohkay, Graduate Student, Instructional Technology
Department of Adult, Career, and Technology, Faculty of Education,
University of Alberta

Title of Thesis: Effects of Computer-displayed Animation on Achievement and Attitude in Mathematics Computer Based Instruction

By signing this form, I hereby agree to participate in the above mentioned research study. Having been contacted by the researcher, I understand that:

1. the purpose of this study is to examine the effects of animation used in computer based instruction on learning outcomes.
2. my name is confidential and will not be disclosed at any time during this study, nor will it be used in the resulting thesis.
3. scores collected in this study will have no effect on my course grade and are confidential.
4. since my participation in this study is purely voluntary, I have the right to quit or stop participating at any time.
5. I may receive the results of the study from the researcher upon request.
6. I may examine the resulting thesis from this study by using the copy that will be available in the University of Alberta Library.

Printed name of participant ______________________________

Signature of participant ______________________________

Date ______________________________

Appendix 2

Authorization For Use of Math 13 CAI Materials

To: Brent Poohkay
From: Michael Szabo
Date: 6 August 1993

RE: Use of animations from Math 13 for purposes of research

I have prepared an agreement for the use of the animations from the Math 13 CBI curriculum for your research leading to the Masters degree in Instructional Technology Education at the University of Alberta. Please review this information and acknowledge your acceptance of the terms by signing two copies and returning them to me. One will be returned for your files. If there are any questions, please call and best of wishes with your research!

The materials, called Math 13 consist of a set of computer files which teach Math 13 concepts from the Alberta Curriculum. The files have been created using educational copies of Authorware Professional for the Mac and Macromind Director and are copyrighted by Alberta Education. As exclusive worldwide licensing agent for these files, I agree to the usage outlined below.

The above mentioned materials may be used or modified by you in order to test research hypotheses which have been approved by your thesis committee and the ethics review committee of the Department of Adult, Career and Technology. A copyright notice must appear prominently on the materials, along with a statement that the materials have been modified for research purposes (should you indeed decide to modify them).

The original or modified materials may not be distributed to anyone outside the research study either directly or indirectly, and must be destroyed upon completion of the study. Packaged copies of the animations used in the study may be included with the thesis in a thesis pocket.

Indicate your comprehension and agreement to these conditions by signing this form and returning to me at your earliest convenience.

Brent Poohkay

Dr. M. Szabo

Appendix 3

Pretest

Following are the nineteen items used for the pretest.

Q.1.

Solve using the Rules for Order of Operations.

$$16 \div 8 + 2^3$$

Q.2.

Simplify using the Rules for Order of Operations.

$$4 \times 50 \div (80 \div 8)$$

Q.3.

Simplify using the Rules for Order of Operations.

$$5\ (5^2 - 5)$$

Q.4.

Determine n in the following. Use your calculator from the Apple menu if needed!

$$n\% \text{ of } 135 = 60$$

Q.5.

Determine n in the following. Use your calculator!

40% of $75 = n$

Q.6.

Determine, without the use of a calculator, $-\sqrt{49}$

Q.7.

The area of a circle is 314 cm^2. Find the radius to 1 decimal place. The formula for the area of a circle is $A = \pi r^2$. (use $\pi = 3.14$)

Q.8.

Determine, without the use of a calculator, $\sqrt{81}$

Q.9.

Evaluate the following. (Round to 3 decimals or leave as a fraction)

5^{-2}

Q.10.

Evaluate. Express your answer as a fraction or a decimal correct to 3 decimal places.

$$25^{15} \times 25^{-15}$$

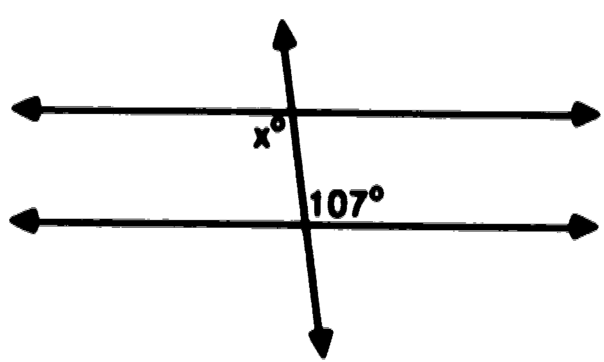
Q.11.

Evaluate. Express your answer as a fraction or a decimal correct to 3 decimal places.

$$\frac{1}{2^{-1} + 4^{-1}}$$

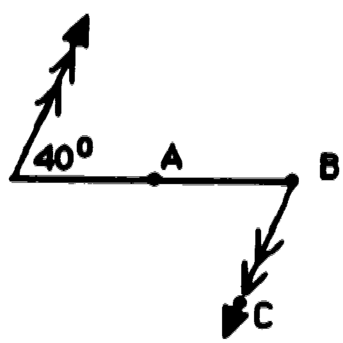
Q.12.

Do the following question using the angle relationships. Solve for x.



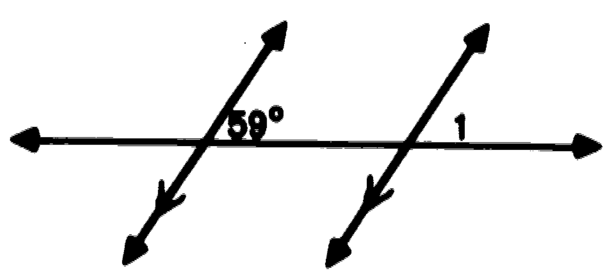
Q.13.

Do the following question using the angle relationships. Find angle ABC.



Q.14.

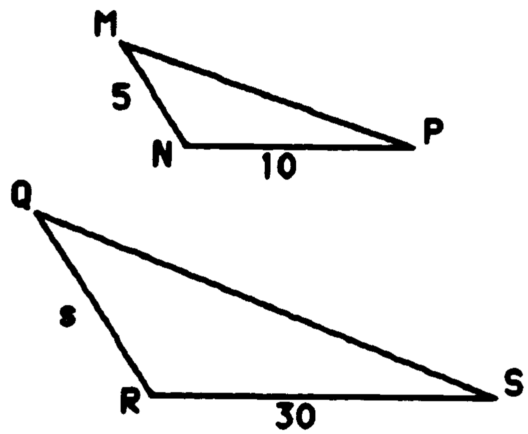
Do the following question using the angle relationships discussed in this and the previous topic.



Q.15.

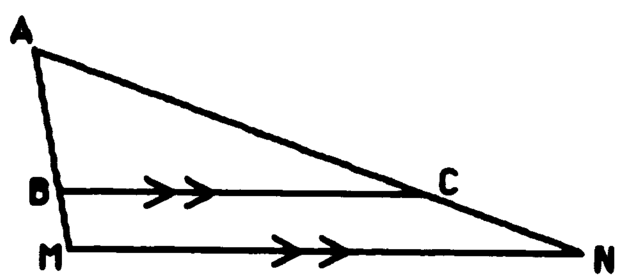
Find the value of QR.

△MNP ∼ △QRS



Q.16.

Refer to the diagram. AB = 3 m, AM = 4 m, and MN = 16 m. Calculate the value for BC.



Q.17.

If △ABC ≅ △DEF, then

b. ∠B ↔ ∠ [ ]

Q.18.

For congruent triangles, the lengths of corresponding sides have the same ______.
(Please click on your choice.)

a. endpoint
c. midpoint
b. measure
d. points

Q.19.

If ΔJHK ≅ ΔRSX, then what else must be true so that the two triangles will be congruent? (Please click on your choice).

a. The corresponding angles must have the same measure.

b. The two triangles must be the same shape

c. The lengths of corresponding sides must be equal.

d. The symbol, ≅ , must be used.

Appendix 4

CBI Math Lessons

Appendix 4 is a computer disk to be found in the enclosed thesis pocket. The computer disk contains electronic copies of the three versions of the computer based instruction lesson used in this study. When prompted, use a three digit identification number with a prefix of one to view the text only CBI lesson. Use a three digit identification number with a prefix of two to view the CBI lesson that uses stationary graphics and text. Use a three digit identification number with a prefix of three to view the CBI lesson that uses computer-displayed animation and text.

Appendix 5

Posttest

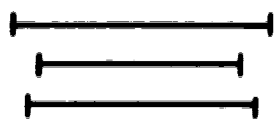
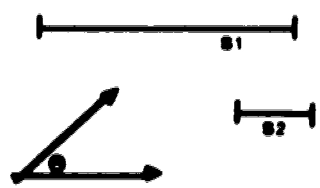
Posttest pages have been scaled to fit page margins.

Post Lesson Questions

Name: ________________

ID Number: ____________

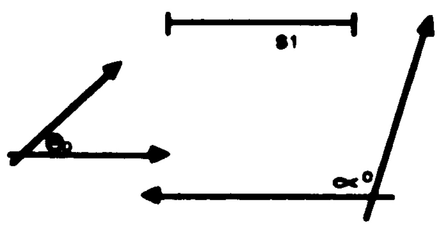
Please complete the following questions using only your compass, straightedge and pencil. If you do not know the answer to a question, try your best.

QUESTION	ANSWER
Construct a triangle from the following line segments. 	
Construct a triangle from the line segments and the included angle. 	
Construct a triangle from sides having lengths of 3 cm, 6 cm, and 7 cm.	

Please continue on the next page...

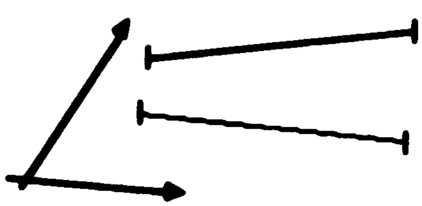
Please complete the following questions using only your compass, straightedge and pencil. If you do not know the answer to a question, try your best.

Construct a triangle from the given angles and included side.



Draw two angles measuring 30° and 45°. Draw a line segment having a length of 10 cm. Draw a triangle given these two angles and the given line segmnent.

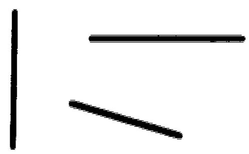
Construct, by SAS, a triangle from the line segments and angle below.

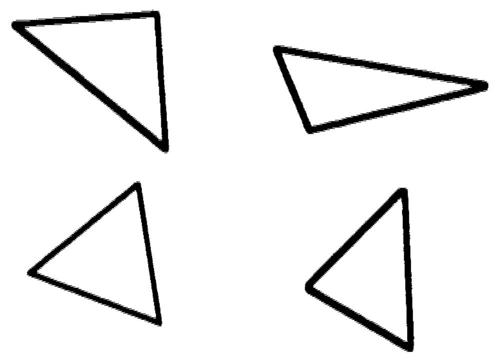


Please continue on the next page...

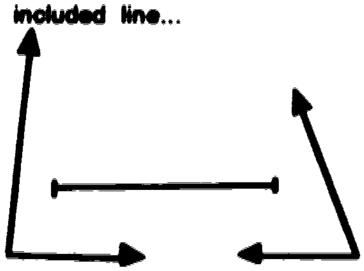
In the following questions, circle the correct answer

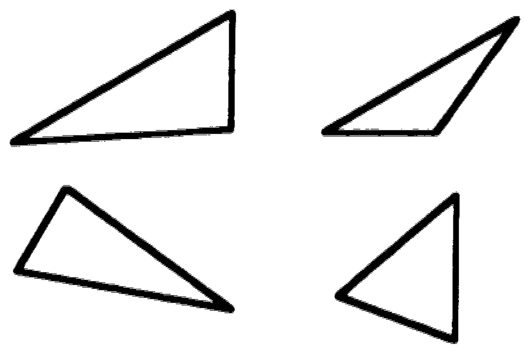
Circle the triangle that was constructed with the following line segments...





Circle the triangle that was constructed with the following two angles and included line...





Appendix 6

Attitude Survey

Following are the list of statements that [illegible] on the post lesson attitude survey. On the pages they were given, subjects were to check a box indicating how they felt toward each statement. Five choices were available; Strongly Agree, Agree, Uncertain, Disagree, and Strongly Disagree.

I felt challenged to do my best work.

I felt as if someone were engaged in conversation with me.

I was more involved in operating the computer than in understanding the course material.

I felt as if I had a private tutor.

The computer made it difficult to concentrate on the course material.

The situation of learning by computer made me quite tense.

Computer assisted instruction, as used in this lesson, is an inefficient use of the student's time.

I felt frustrated by the situation.

I found the computer assisted instruction approach in this course to be inflexible.

Material which is otherwise interesting can be boring when presented by CAI.

I would prefer computer assisted instruction to traditional instruction.

Computer assisted instruction is a step toward de-personalized instruction.

I was concerned that I might not understand the material.

I felt uncertain as to my learning in the computer course relative to the learning of others.

I found myself trying to get through the material rather than trying to learn.

When I am trying to learn things, it is important to me to know where I stand relative to others.

I guessed at the answers to some questions.

In view of the time allowed for learning, I felt too much material was presented.

I felt I could work at my own pace.

I was aware of the slow speed of the computer while I was taking the course.

Material which is otherwise boring can be interesting when presented by CAI.

I could have learned more if I hadn't felt pushed.

The course material was presented too slowly.

Computer assisted instruction did not make it possible for me to learn quickly.

While on computer assisted instruction, I encountered mechanical malfunctions.