DESIGN, DEVELOPMENT, AND IMPLEMENTATION OF A COMPUTER-BASED GRAPHICS PRESENTATION FOR THE UNDERGRADUATE TEACHING OF FUNCTIONS AND GRAPHING

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

Rosemary McCroskey Karr, B.S., M.A.

Denton, Texas

December, 1996

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The problems with which this study was concerned were threefold: (a) to design a computer-based graphics presentation on the topics of functions and graphing, (b) to develop the presentation, and (c) to determine the instructional effectiveness of this computer-based graphics instruction. The computerized presentation was written in Authorware for the Macintosh computer.

The population of this study consisted of three intermediate algebra classes at Collin County Community College (n = 51). A standardized examination, the Descriptive Tests of Mathematics Skills for Functions and Graphs, was used for pretest and posttest purposes. Means were calculated on these scores and compared using a t-test for correlated means. The level of significance was set at .01. The results of the data analysis indicated:

1. There was a significant difference between the pretest and posttest performance after exposure to the computer-based graphics presentation.

2. There was no significant gender difference between the pretest and posttest performance after exposure to the computer-based graphics presentation.

3. There was no significant difference between the pretest and posttest performance of the traditional and nontraditional age students after exposure to the computer-based graphics presentation.

Females had a lower posttest score than the mean male posttest score, but an analysis of the differences showed no significance. Traditional age students had a higher posttest performance score than the mean traditional age student posttest score, but their pretest performance scores were higher as well. An analysis of the differences showed no significance. In summary, this computer-based graphics presentation was an effective teaching technique for increasing mathematics performance.

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CHAPTER I

INTRODUCTION

While pedagogical approach is uniquely determined by each instructor at the college level, certain technological tools have become available that could potentially enhance instructors' teaching effectiveness. The introduction of the microcomputer opened the doors of opportunity for many due to its power, reduced size, and low cost (Doerr, 1979). Computer hardware continues to increase in power while concurrently decreasing in cost; yet evidence of its effective application as an educational tool is needed. Govea (1989) has expressed concern over the under-utilization of current technology. "If the early 1980s brought the promise of a computer revolution in higher education, the late 1980s have brought the frustration of a failed revolution" (p. 153). The potential use of the computer as a unique presentation tool has been overlooked, or perhaps overshadowed, by the powerful strength it possesses as an infinitely patient, individualized tutor. Computers have had the capability of changing the face of American higher education for decades, and yet, they are just recently emerging as a viable classroom presentation tool. Dugdale et al. (1995) state, "More attention needs to be directed toward creating model curricula for use with existing software tools, and toward doing the necessary research to provide guidance to new curriculum designers" (p. 343). This paper explored the impact of this alternative form of classroom presentation.

Many roadblocks exist to the full incorporation of this medium, not least of which is user resistance. The 1980s witnessed uncertainty and ignorance on the myriad options of computer systems. This was not surprising due to the sometimes overwhelming speed with which technological changes were occurring. The various computer manufacturers and the multiple options available within each brand kept the fear and apprehension of computers alive. When a buyer took the plunge, the purchased unit decreased in price quickly and more desirable features were developed for the newer models, typically within the span of a few months (Capron, 1992).

The 1990s characterize a new attitude among educators. It is rare to find a faculty office without a computer. The few resistant faculty have been forced to accept this technology for its electronic mail and fax capabilities alone, notwithstanding the word processing application. This wide acceptance of technology among educators has begun to carry over into the classroom, beyond tutorial purposes. Although progress is slow, classroom presentations are being done via the computer. The next and necessary step is increased research efforts in measuring the impact of this technology on student learning.

Microcomputers offer a new tool to aid in society's goal of mass education. This new paradigm of utilizing the computer in mathematics classes is in its infancy. Software packages are currently being utilized for "number crunching" activities in classes such as statistics and numerical analysis. Webster (1992) and Doerr (1979) refer to the computer as a mathematical tool, resolving problem solving time constraints by reducing the tedium of calculations and allowing for exploration of real world problems that are beyond pencil-and-paper calculations. The innovative use of technological resources will vary by professor and institution. Govea (1989) discusses the "old school" of teaching, admitting many faculty lack the ability to go beyond the pervasive norm of teaching statistics without extensive calculations and formulas. This inadequate technological preparation permeates all areas of mathematics and society.

Computer software extends beyond use as a computational time-saver; it can also be viewed in terms of its usefulness in illustrating mathematical concepts. Numerous topics could be enhanced through appropriate technological application of computer graphics. Computer software should be seen as a means to an end, not the end itself. With the integration of computer-based graphics, by professionals, into the presentation of the curriculum, software can be one means to the end goal of well-developed problem-solving skills. Doerr (1979) describes the steps required to effectively obtain the computer aided solution to a problem as the teaching of problem-solving skills, from a thorough analysis of the problem, to sequencing the necessary steps, to an analysis of a "reasonable" solution.

Faculty have faced three major difficulties in relationship to the microcomputer and its use in the mathematics classroom. The first difficulty was that many faculty were unfamiliar with the classroom application of the microcomputer. There was demand for administrative support of teaching improvement comparable to the research support system that currently existed. "Most universities now encourage and reward faculty research over improvements in teaching. Thus, it will not be easy for faculty to take the brave steps needed to risk the time and effort in lieu of research with its proven payoffs" (Baird, 1986-1987, p. 51). Second, faculty were untrained in the techniques needed to incorporate computer technology into their pedagogy. Balla (1987) identified the need for staff development programs that support the increased use of computers in the classroom. The third concern was the inadequate administrative financial support of hardware and software purchases as well as the ongoing cost of maintenance. Doerr (1979) discussed the nonconformity of computers in regard to the Hawthorne effect. Their effectiveness did not pale when the novelty of this innovation wore off.

There are numerous research results supporting computer-assisted instruction (CAI) and its usefulness in the mathematics classroom. These studies were conducted in the late 1960s and the 1970s. The 1980s began studies in the area of classroom usage of computers with teacher led demonstrations. Many studies involved computer-enhanced instruction (CEI) that covered multiple, sometimes indistinguishable levels of classroom computer use. For this research, the computer-based graphics presentation was considered a form of CEI. This new term was introduced to clearly distinguish between an instructor led computerized classroom presentation and the somewhat ambiguous term of CEI. The strengths of this technique is its ability to work with real-life data due to the computer's number crunching capabilities and to demonstrate abstract mathematical concepts.

Computer-based graphics presentations are a paradigm shift that needs to be researched. How can modern technology contribute to the field of education and the development of problem-solving skills? Technology and technological software are not inherently beneficial to the attainment of our educational objectives. When coupled with competent educators and financially supportive administration, we have set the stage for higher levels of student achievement. An evaluation of the educational application of a computer-based graphics presentation for the mathematics classroom merited examination, due to its effect on student understanding.

Statement of the Problem

The problem of this study involved the design, development, and empirical testing of a computer-based graphics presentation for the teaching of functions and graphing.

Purposes of the Study

The purposes of this study were to: (a) design a computer-based graphics presentation for the teaching of functions and graphs; (b) develop the computer-based graphics presentation; and (c) implement the presentation, measuring subsequent changes in student performance.

Research Hypotheses

1. There will be a significant difference between the pretest and posttest performance of students exposed to the computer-based graphics presentation.

2. There will be no significant difference between the pretest and posttest performances of males and females exposed to the computer-based graphics presentation.

3. There will be no significant difference between the pretest and posttest performances of traditional and nontraditional age students exposed to the computer-based graphics presentation.

Significance of the Study

Major expenditures on computer hardware, its maintenance, and software must be justified through research that investigates the potential benefits achieved from the use of such technology. These benefits include increased levels of student understanding; student motivation; computer skills; job marketability; productivity of teaching; student confidence; opportunity for feedback, a crucial factor in learning; and relevant application of mathematics. Movement toward the eradication of the fear of mathematics for future generations may occur if we utilize technology to reduce the memorization and mystique of the subject and teach for discovery and understanding of the concepts. This research assessed the efficacy of computer-based graphics instruction as a mode of presentation for enhancing mathematics performance in college algebra students.

Borg and Gall (1989) describe this type of study as improvement research since its primary purpose is the potential improvement of student learning. This was not an attempt to prove that computer-based presentations are superior to traditional lecture approaches. Rather, this was an investigation of whether a computer-based graphics presentation is a viable alternative to traditional lectures for the topic of functions and graphs.

Delimitations of the Study

1. The study was restricted to intact groups of three intermediate algebra classes at one particular community college in Texas.

2. There was no randomization of students.

3. There was no randomization of classes.

Definition of the Terms

Computer-augmented learning--educational use of the computer to supplement a more conventional instructional method.

Computer-assisted instruction (CEI)--educational use of the computer as a tutor for individualized learning.

Computer-based graphics--all forms of educational computing that use computer-generated visual aids.

Computer-based graphics presentation (CBGP)--a classroom presentation, instructor led, that uses the computer to display information, utilizing graphs

Computer-enhanced instruction (CEI)--a classroom presentation that uses the computer as a supplement to traditional lecture instruction.

Function--a correspondence between two sets where one element from the first set is paired with exactly one element from the second set.

High level performance--concept acquisition demonstrated at the analysis, synthesis, or evaluation level.

Low level performance--skill acquisition demonstrated at the knowledge, comprehension, or application level.

Microcomputer--a small, inexpensive computer that performs input, processing, storage, and output. Commonly referred to as a personal computer (PC).

Relation--a correspondence between two sets.

Storyboard--a detailed, written outline of each slide of a computerized presentation.

Traditional age--students between the ages of 18 and 22 years (Pascarella & Terenzini, 1991).

Introduction to the Organization of the Dissertation

Chapter 2 traces the historical evolution of computers in education and amplifies the call for empirical research on the topic of computer-based graphics presentations. Chapter 3 provides the outline of data collection and analysis. A single-group pretest/posttest design was employed with the dependent variable being performance. A pretest (DTMS) was given, followed by the presentation (CBGP), and ending with a posttest (DTMS). The analysis was a t-test for correlated samples, since each student served as his/her own control. A detailed analysis of the empirical data is provided in Chapter 4. Recommendations are abundant and are discussed in Chapter 5.

REFERENCES

Baird, W. E. (1986-1987, Winter). The influence of computers and informatics on mathematics and its teaching. The Journal of Computers in Mathematics and Science Teaching, pp. 49-51.

Balla, J. (1987). Microcomputers and teaching school mathematics: An answer to the challenge. Australian Mathematics Teacher, 43(1), 2-4.

Borg, W. R., & Gall, M. D. (1989). Educational research (5th ed.). White Plains, NY: Longman.

Capron, H. L. (1992). Essentials of computing. Redwood City, CA: Benjamin/Cummings.

College Entrance Examination Board. (1989a). Descriptive test of mathematical skills for functions and graphs. New York: Author.

Doerr, C. (1979). Microcomputers and the 3 r's: A guide for teachers. Rochelle Park, NJ: Hayden Book.

Dugdale, S., Thompson, P. W., Harvey, W., Demana, F., Waits, B. K., Kiernan, C., McConnell, J. W., & Christmas, P. (1995). Technology and algebra curriculum reform: Current issues, potential directions, and research questions. Journal of Computers in Mathematics and Science Teaching, 14(3), 325-357.

Govea, R. M. (1989). Some observations on computer education for political science students. Teaching Political Science: Politics in Perspective, 16(4), 153-156.

Pascarella, E. T., & Terenzini, P. T. (1991). How college affects students. San Francisco: Jossey-Bass.

Webster, E. (1992). Evaluation of computer software for teaching statistics. The Journal of Computers in Mathematics and Science Teaching, 11, 377-391.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

After perusing the literature on the subject of computer-based graphics presentations as a substitute for traditional lecture instruction, four recurring themes emerged. First, communication of research results is hampered by the lack of standardization of keywords in the educational application of computers. Second, an insufficient number of computer-based graphics presentation packages are available for instructor use. Third, institutions are promoting pedagogical use of the computer without adequate resources or support that could potentially optimize their effectiveness. The last major point is that most of the packages that are available and in use have not been tested for their educational impact. This review discusses each of these themes, including an overview of computer-based graphics, the educational integration of the microcomputer, and a discussion of the teaching effectiveness of computer-based graphics presentations (CBGP). While other disciplines have also utilized CBGP, mathematics is the area of concentration for this review. The following represents an omnibus work on research involving the pedagogical use of computer-based graphics presentations for the mathematics classroom.

The terminology within educational literature is inconsistent and ambiguous as it relates to computers used in teaching and learning research. The late 1960s and early 1970s found the term computer-assisted instruction (CAI) commonly accepted for tutorial, drill and practice exercises, and laboratory assignments. The 1970s brought numerous journal articles on the classroom use of technology, replete with new terminology, but with no clear distinctions being made among the terms. For example, computer-supported drill and practice, computer-assisted instruction, computer-based teaching, and computer-augmented instruction were introduced and have all been used interchangeably with CAI. While the literature reflects differences between each of these terms and CAI, many authors have not differentiated among them. The common thread and the focus of that literature was on computers primarily used as a learning tool. The focus of this review was on computers used as a teaching tool. The most widely accepted generic keyword for computers used as a teaching tool is computer-enhanced instruction (CEI), although this too has been misused in the reviewed literature to describe CAI.

Many of the obstacles that occur with CAI do not occur with a computerized presentation. For example, student characteristics such as gender and keyboarding ability have been found to affect CAI results but do not seem interact with the teacher's use of the technology (Johnson & Perez, 1996). This is reasonable since the student is not required to use the computer during CBGP.

The second recurring theme in the literature is the inadequate number of CBGP packages available for classroom use. Furthermore, those that are available are limited in scope. An analogy could be made to the initial stages of commercial videotapes. Twenty years ago, one would primarily go to the library to pick up a videotape of some public broadcasting program. As the interest and demand for tapes increased, industry responded. Today, video-rental stores are abundant. Similarly, as the demand for computer-based instructional presentation packages grows, industry will respond. Book publishers are a natural choice to pioneer the development of presentation packages, if there is sufficient demand for this product. Through a standard procedure, publishers hire professors and curriculum development specialists to write the material that they will, in turn, market. Wilson (1994) urges educators to monitor the process for a product that educationally meets our needs. An important point made by Willows and Houghton (1987) concerned optimizing learning outcomes. They encourage researchers, producers, and consumers of educational text to work together in an ongoing process of improvement. If the textbooks would reflect a new approach and perhaps publishers provided canned presentation packages for classroom demonstrations as they currently do for student tutorial work, the integration of technology would increase rapidly. The textbook publishers are in a position to help set the pace for the integration of technology into the educational pedagogy (Greenfield, 1993).

An alternative solution to the inadequate number of presentations is for teachers to develop their own storyboards through their mathematical expertise, pass the designed material on to computer staff, and have that staff member put the information in an animated software package. Misunderstandings abound in the role the teacher must take, many mistakenly believing they must do the programming themselves. Ease of use of technology is a critical factor in the rate of development of all aspects of computer use. This was true for CAI and is true for CEI as well.

Third, institutions are promoting pedagogical use of the computer without adequate resources or support that could potentially optimize their educational impact. This refers to the hardware but, more importantly, to the lack of teacher training. There has been a firm commitment on the part of administrators, parents, and teachers to have ample computer technology for educational purposes. There is a positive correlation between the resources of an institution and its reputational ranking; that is, schools with high reputational ranking tend to have excellent resources and vice versa. Today, a form of institutional prestige is achieved with increased computer assets and capabilities. The trend is to buy as much equipment as the budget can support. The possession of computer technology is not a necessary condition for an institution to be of high quality, nor is it sufficient. Rather the sound pedagogical implementation of computers must remain the focal point. This requires a financial commitment to the training and staff needed for optimal utilization of the equipment.

It is ultimately the teacher who is responsible for the pedagogical integration of computers into the curriculum (Dugdale et al., 1995). In the past, the primary use of computers was for record keeping, attendance, grade calculations, and reports. CAI, though, quickly became an integral part of the mathematics curriculum. There was financial support for this endeavor through federal grants and from the corporate world. Faculty applied for grants from agencies, such as the National Science Foundation, to gain financial support for the educational integration of computers in the classroom. Unfortunately, teachers have not been trained on the operational idiosyncrasies of the machine, the capabilities of the technology, or the appropriate educational use of computers. They are groping in the dark, competent in their field of expertise, but lacking computer skills necessary for implementation of technology (Wiley, 1993). They have hopped on board the technology bandwagon, working endless hours for self-training to bring themselves up to speed. To aid in these efforts, many higher education institutions offer staff development courses on the world wide web, spreadsheets, and word processing. The dilemma is when do faculty find the time to develop technologically when they are met with the daily challenges of education? To have a successful program of computer implementation, faculty must have the physical resources, i.e. the computer, the training, and the support staff to integrate mathematical knowledge with the computer manipulation of that knowledge.

The last recurring issue is that most of the computer-based presentation packages that are available have not been tested for their institutional impact. The literature repeatedly reflects the use of technology in the classroom but does not empirically test the resulting impact. Keywords such as "describes," "examines," and "discusses" are used for abstracts of the journal articles found on various mathematical software currently being considered and adopted in education.

In-house, faculty developed computer-based presentations are rapidly growing as well, but again, limited data are available to assess computer impact on student learning. The design component of the presentation alone demands instructional design knowledge, subject expertise, software knowledge, and a resource for implementing the design in the software. Clear performance objectives must be established, detailed lesson plans for strategic achievement of stated objectives must be written, and a measuring tool for summative evaluation of the product must be designed prior to the technological aspect of the presentation. In addition, a teacher cannot design a presentation that the chosen software is incapable of performing. The teacher must be aware of the computer's capabilities and limitations. Once the presentation is implemented, the research results have limited generalizability due to the use of intact groups, a common problem for educational studies. This exacerbates the accountability issue in teaching. How can educators continue to teach, develop technological skills, develop computerized presentations, and demonstrate the impact on students through learning research?

In the 1970s, computer-assisted instruction was the buzzword, becoming the most pervasive form of computer usage in education. It has been thoroughly researched and found to be a viable alternative to traditional lecture (Alesandrini, 1982). Education has embraced CAI, and it continues to flourish, particularly in the field of mathematics.

Beyond CAI though is CEI. There is a need for CEI research. This is not surprising since those educators who have embraced the technology have been busy developing the classroom presentations. While there is an abundant amount of information on CAI and its effect in the classroom, the primary source of information for computer-based graphics presentations, although limited, has come from doctoral dissertations. There is a need in education to parallel the extensive research that has been done for CAI with research for computer-based graphics presentations.

Overview of Computer-Based Graphics

The use of pictures to enhance communication can be traced back as far as paintings on cave walls. Black (1988) asserts that computer graphics surpasses chalkboard graphics by going beyond the mere representation, analogical, and abstract classifications of graphics into the dynamic changes and comparisons it is uniquely capable of demonstrating. Baird (1986-1987) refers to computer graphics as a "dynamic chalkboard," offering faculty new pedagogical classroom opportunities. The computer is unique in its ability to enhance mathematical concepts, creating a more interesting and enjoyable student experience (Gordon & Gordon, 1989). Goldenberg (1988) encourages the use of technology to change the focus from lower level skills to the higher level skills made accessible through the advances of computer technology. Research (Byers, 1974; Johnson, 1994; Mayes, 1995) supports this philosophy, indicating empirical results of CEI performance skills comparable to traditional lecture results, yet higher order thinking skills from exposure to CEI do significantly differ and are higher than results from traditional lecture instruction.

The process of developing an effective computer-based graphics presentation begins with the identification of mathematical topics for which the computer can uniquely contribute to student understanding. Many topics lend themselves to this process including the Central Limit Theorem, the Taylor Series, geometric concepts, and functions. Smith (1982) finds the computer useful for answering "what if?" questions about changes in problem parameters, graphically demonstrating the significance of parameter manipulation. Computers have had a major impact for such classes as Statistics, Number Theory, Group Theory, Regression, and Combinatorics (Bajgier, Atkinson, & Prybutok, 1989; Baird, 1986-1987; Gilligan, 1991; Webster, 1992). The computer uniquely affords the opportunity to study real-world functions due to their number crunching capabilities, increasing the ability to manipulate difficult equations in a classroom environment.

Microcomputers are particularly useful in emphasizing techniques such as visualization, simulation, and problem-solving. (Alesandrini, 1987; Baird, 1986-1987; Dugdale et al., 1995; Howles & Pettengill 1993; Zimmermann & Cunningham, 1991). Dugdale (1982) states, "This ability, coupled with the growing availability of low-cost computers with sophisticated display capabilities, makes computers a natural choice for materials intended to improve students' understanding of functions and graphs" (p. 208). Use of graphics promotes comprehension and retention while concurrently enhancing enjoyment and interest.

"Computer graphics has many potential uses in the classroom, particularly with young students who are more visually than verbally oriented" (Bitter & Camuse, 1988, p. 57). A study by Houston (1993) indicates that learning styles may be a factor in the effective use of the computer. In contrast, Ingram (1987) found that exposure to computer-augmented teaching in an American government class did not vary significantly with learning style. This finding is supported by McGrath's (1993) study that found no relationship in class performance and learning styles in a college computer science class. Clariana and Schultz (1993) recommend that learning styles be matched with instructional technique preferences, allowing the students to choose their preferred method of instruction. Johnson and Perez (1996) call for descriptive models of the characteristics of learners that are related to success. Goldenberg (1988) states, "Common sense supports the notion that multiple representation will aid understanding" (p. 136). Tapping into multiple modalities can only enhance student learning.

Educational Integration of the Microcomputer

Computer sophistication has progressed through several "generations" since computers were first developed in 1823. Pioneers in the development of computer technology include: Charles Babbage, Ada Augusta Byron, Herman Hollerith, John Atanasoff, Howard Aiken, Grace Hopper, John Mauchly and J. Presper Eckert. Originally, the desire to increase the speed and efficiency of arithmetic calculations spurred the development of Babbage's Analytic Engine. The usefulness of computers centered on scientific applications until, in 1946, the first company was formed to build commercial computers. Vacuum tubes, as the basic electronic component, marked the first generation of computers, 1940's-1958. The second generation of computers, 1959-1964, introduced transistor technology. The advantages accrued from the transistors replacement of the vacuum tubes were decreased size, increased speed, and reduced air conditioning needs. Integrated circuits marked the third generation, 1964-1975, resulting in decreased cost, thus, increasing the number of users. The fourth generation, 1975-1985, was marked by the large scale integrated circuit and resulted in the development of the microcomputer (Capron, 1992). Many of the technological developments were encouraged through government grants to higher education institutions. After the initial development by higher education institutions, the normal course of action followed; that is, the business community developed the product for commercial use. It is this commercial development of the microcomputer through APPLE, Tandy Corporation, Atari, and Commodore that began the vision of myriad opportunities for pedagogical change in the classroom.

Computers have not been rapidly integrated within educational curricula, but rather have seen a slow, gradual increase in usage. Software that involves computer-aided instruction programs are available and prolific. In contrast, computer-based classroom presentations in mathematics are, for the most part, left to the individual instructor to design. Inhibitors to microcomputer acceptance in education have been identified by Silberman (1969) including facilitating man-machine communication, cost efficiency, and user acceptance. Other factors identified by Doerr (1979) are insufficient software, inadequate research, and the need for teacher training. "The training of new and old faculty, the development of effective courseware, wide-ranging research into ways the computer can promote learning in mathematics, and other, as yet unforeseen, problems must be overcome before the computer can reach its potential" (Baird, 1986-1987, p.51). Educators' reluctance to introduce microcomputers in the classroom, Doerr believes, may be due, in part, to the belief they must develop their own software. While they do typically design their own instructional content, programming skills are not a requisite skill for classroom computer usage. Black (1988) contends that the dearth of computer-augmented teaching software, the need for large screens in the classroom, and the deficiency of instructor preparation are three major inhibitors to the incorporation of the microcomputer in education. "Foremost among them is the need to continue teaching full time while developing better teaching techniques, leaving them little time for planning and implementation" (p. 49). In addition, the perceived threat of the computer as a replacement of the teacher slowed the initial implementation of this technology. Fear of lost jobs or simply loss of classroom control motivated teachers to investigate this potential medium. After teachers understood the benefits, uses, and limitations of the computer, did they embrace this new tool. The computer was not a replacement but gave the teacher an opportunity to redirect their attention to instructional design. Increased time and attention could be spent on specifying objectives and measurement of the attainment of stated objectives.

Butzin (1992) points out the problem for administrators and educators alike of "retrofitting technology to the existing structures of education" (p. 330). Classrooms must be redesigned and wired to support the new technology. Yet, the technology is changing and improving so rapidly that even corporations have a difficult time keeping up with the changes. What used to be called the cutting edge of technology is now referred to as the bleeding edge, since the new technology is expensive, yet in a matter of a few months, prices drop significantly and new computer capabilities emerge. Wilson (1994) cautions that higher education can ill afford the "megamistakes" made by industries in their quest to stay on the technological edge.

Computers provide a plethora of educational uses including testing, demonstration, tutorial, administrative bookkeeping, word processing, graphics, spreadsheets, telecommunications, statistical studies, and laboratory exercises. Their current use in the mathematics classroom is primarily attributed to computer-assisted instruction which involves drill and practice, tutorial, simulation, computer-managed instruction, problem solving, and special needs (Bitter & Camuse, 1988; Doerr, 1979;

Lumsden, 1974). Today, computers are being used, not just for mundane drill and practice, but to teach abstract mathematical topics.

Mathematics is perceived by many to be difficult to understand, and therefore, is more easily memorized than learned. Hampered by this attitude, it is incumbent upon the instructor to illustrate why mathematics works as it does, to increase understanding rather than a memorization of rules (Teles, 1991). The computer is a relatively new pedagogical tool available to aid in increasing student understanding of a somewhat difficult subject. "The primary purpose of using a computer in the mathematics classroom should be to enhance the mathematical concepts, not to substitute for the instructor's insights or approach. It should help the teacher and the student by making the course more interesting for both" (Kemeny, 1991, p. 35). Bland (1984) cautions the overuse of computers in the classroom, encouraging selectivity of mathematical topics, those especially suited to the unique capabilities of a computer demonstration.

"Assuming that enjoyment, activity, and relevance improve the quality of the learning process, it is likely that the future 'mix' of pedagogical approaches will include more (rather than less) computer supplemented education" (Gray, 1973, p. 148). Increased student interest increases student motivation which, in turn, affects performance. Graphics demonstrations can heighten interest, motivation, and enjoyment (Willows & Houghton, 1987). There is a need for experimental research in this area due, in part, to the obvious lack of research as well as the potential impact the results could have in the future direction of educational strategies. Computer-based graphics presentations need to be continually improved, expanded in terms of use, and evaluated for their instructional effectiveness.

Teaching Effectiveness of Computer-Based Graphics Presentations

Schneider (1977) describes three areas of computer supported instructional research: (a) performance research, (b) attitude research, and (c) behavioral research. He states that performance research "refers to the acquisition and retention of selected concepts and skills" (p. 318), attitude research is an "increased student sensitivity toward both computers and the subject matter"(p. 319), and behavioral research is an "increased student use of computers and statistics in environments other than the particular course in which these subjects were initially encountered" (p. 319). Few studies have evaluated the effectiveness of computer-enhanced instruction in any of these areas of research. The comparison of the research done on what the literature refers to as computer-enhanced instruction is difficult. The diverse nature of the mathematical topics, diverse formats of study, diverse educational levels, diverse software, diverse teacher training, diverse student backgrounds, and diversity of schools all limit the comparisons. There have been, at best, isolated empirical studies. Johnson and Perez (1996) state, "Unfortunately, almost no research has been conducted to determine the effectiveness of computer-based approaches" (p. 3).

In general, several trends have begun to establish themselves. First, the majority of findings indicate student learning through traditional lecture and computerized presentations show no significant differences in student performance of class objectives. This demonstrates that CEI is doing as well as traditional lecture on student performance of low-level objectives. Second, student attitudes are significantly more positive under the CEI when compared to the student attitudes after traditional lecture instruction (Ganguli, 1992; Sutherland, 1993). Third, there is an indication, or perhaps suspicion, that higher order thinking skills may be improved after exposure to CEI (Dugdale et al.

1995; Kulik, 1991; Kulik, Kulik, & Cohen, 1980; Mayes, 1995). These skills could involve long-term memory, reduced time for instruction, and increased understanding.

Studies on computer-based presentations have focused on the investigation of specific computer software programs. Much of the empirical evidence for effectiveness has been found through dissertation research. Imboden (1985) did an exploratory study using computer-enhanced instruction of percents with low-achieving college students. His primary interests were in achievement, time requirements, attitudinal changes, and gender differences. Although he found no differences in achievement, attitude, or gender between CEI or traditional lecture, he did find CEI allowed more time for more in-depth discussion. His results lend credence to the theory that CEI does indeed promote student achievement of the basic course objectives.

Mayes (1995) found manipulation and computational skills of CEI equivalent to those of traditional lecture. The importance of his research was that he did find significant increases in inductive reasoning skill, visualization, and problem solving. In a different study using intact groups and computer-enhanced instruction (CEI) for the teaching of linear absolute value inequalities, Kiser (1990) found achievement levels were significantly raised for the CEI group as compared to the traditional lecture group.

Other studies have been done, not in comparison to traditional lecture, but in measuring the impact of CEI on student learning. Edwards (1982) effectively used CEI in linear algebra, while Bland (1984) and Stockburger (1982) used microcomputer graphics to effectively demonstrate statistical concepts. A meta-analysis performed by Khalili and Shashaani in 1994 indicated "that the instructional use of the computer increases students' academic achievement" (p. 57). In 1983, Nygard and Ranganathan studied the successful application of interactive graphics for the enhancement of problem solving in mathematics.

CBGP affects both the cognitive and affective domain. In a study conducted by Gray (1973), the result was positive attitudinal changes due to the increased relevancy of assigned problems made possible by the use of a computer. Although his study was conducted in business administration, similar results have been found in statistics classes (Neter & Chervany, 1973). Byers (1974) did research on both the performance and attitudinal changes of students enrolled in Quantitative Analysis. He found students exposed to computer-enhanced instruction performed at the same level as students exposed to the traditional lecture on basic cognitive skills. Byers did find positive attitudinal changes toward computing in the students exposed to the computer supplemented instruction.

Despite recent trends toward accountability, much research remains to be done, a need identified by many (Bland, 1984; Clariana & Schultz, 1993; Gilder, 1993; Johnson & Perez, 1996; Kiser, 1990; and Prybutok, Bajgier, & Atkinson, 1991). As Kemeny (1991) asserts,

> There is no single best way to use computers in the mathematics classroom. The methods depend on the subject, student background, and individual teaching style. But there is a single worst way-not to use the computer at all. ...you are depriving your students of a wonderful pedagogical tool." (p. 37)

This technological medium could be cogently expressed as effective. The next obvious question, is it worth the price? Super (1993) suggests a Return on Investment analysis of new educational technology projects similar to those done in the corporate world.

In summary, computers are beginning to take their rightful place in the pedagogical world of education (Galbreath, 1992). Fear has been minimized and excitement continues to grow for teachers and students alike. Empirical research efforts need to be intensified for CEI. Dugdale et al. (1995) state that research must "not only examine students' cognitive gains, but must look at appropriate mechanisms for teacher support" (p. 314). Few classroom presentation packages have been evaluated at all, and those packages that have been evaluated report no significant difference in student learning levels of basic course objectives when compared to traditional lecture instruction. The results of low-level performance discussed in Bloom's taxonomy for cognitive learning seems unaffected by method of presentation. Research does, however, report significant changes in student's attitudes and supports the theory that high-level performance skills may have significantly higher results for CEI. Johnson and Perez (1996) give an excellent synopsis of the current status of CBGP, "The application of computer-based instruction to developmental education is an area ripe for further investigation, especially given the scale of the need for developmental education and the societal and institutional factors driving the integration of technology into instructional programs" (p. 13). While integrating technology and education may sometimes seem like a portentous task, this union holds the promise of improving the effectiveness of higher education.

REFERENCES

Alesandrini, K. L. (1987). Computer graphics in learning and instruction. In D. Willows and H. Houghton (Eds.), The psychology of illustration, 159-188. New York: Springer-Verlag.

Baird, W. E. (1986-1987, Winter). The influence of computers and informatics on mathematics and its teaching. The Journal of Computers in Mathematics and Science Teaching, pp. 49-51.

Bajgier, S. M., Atkinson, M., & Prybutok, V. R. (1989). Visual fits in the teaching of regression concepts. The American Statistician, 43(4), 229-234.

Bitter, G. G., & Camuse, R. A. (1988). Using a microcomputer in the classroom (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Black, K. J. (1988, May/June). Computer-augmented teaching: The computer screen versus the chalkboard. Academic Computing, pp. 46-49.

Bland, J. M. (1984). Using a microcomputer as a visual aid in the teaching of statistics. The Statistician, 33, 253-259.

Butzin, S. M. (1992, December). Integrating technology into the classroom: Lessons from the project CHILD experience. Phi Delta Kappan, pp. 330-333.

Byers, C. R. (1974). A comparison of computer-supported instructional techniques in statistics. In G. W. Dickson (Ed.), Monograph on innovative education (pp. 57-89). Atlanta, GA: The American Institute for Decision Sciences.

Capron, H. L. (1992). Essentials of computing. Redwood City, CA: Benjamin/Cummings.

Clariana, R. B., & Schultz, C. W. (1993). Gender by content achievement differences in computer-based instruction. Journal of Computers in Mathematics and Science Teaching, 12(3/4), 277-288.

Darken, B. (1995, February). American mathematical association of two year colleges: Standards for developmental and introductory college mathematics. In J. L. Higbee & P. L. Dwinell (Eds.), Selected conference papers (pp. 7-8). Chicago: National Association of Developmental Education.

Doerr, C. (1979). Microcomputers and the 3 r's: A guide for teachers. Rochelle, NJ: Hayden Book.

Dugdale, S. (1982). Green globs: A microcomputer application for graphing of equations. Mathematics Teacher, 75, 208-214.

Dugdale, S., Thompson, P. W., Harvey, W., Demana, F., Waits, B. K., Kiernan, C., McConnell, J. W., & Christmas, P. (1995). Technology and algebra curriculum reform: Current issues, potential directions, and research questions. Journal of Computers in Mathematics and Science Teaching, 14(3), 325-357.

Edwards, S. E. (1982). Use of microcomputers at the junior college level in teaching of mathematics. Unpublished master's thesis, San Jose State University, San Jose, CA.

Galbreath, J. (1992, April). The educational buzzword of the 1990s: Multimedia, or is it hypermedia, or interactive multimedia, or ...? Educational Technology, pp. 15-19.

Ganguli, A. B. (1992, December). The effect on students' attitudes of the computer as a teaching aid. Educational Studies in Mathematics, 23(6), 611-618.

Gilligan, W. P. (1991). The use of a computer statistical package in teaching a unit of descriptive statistics (Doctoral dissertation, Boston University, 1990). Dissertation Abstracts International, 51, 2302A.

Gilder, G. (1993, March). The information revolution. The Executive Educator, pp. 16-20.

Goldenberg, E. P. (1988). Mathematics, metaphors, and human factors: Mathematical, technical, and pedagogical challenges in the educational use of graphical representation of functions. Journal of Mathematical Behavior, 7, 135-173.

Gordon, F. S., & Gordon, S. P. (1989). Computer graphics simulations of sampling distributions. Collegiate Microcomputer, 7(2), 185-189.

Gray, C. (1973). Expressed student attitude toward conventional versus computer supplemented instruction. Decision Sciences, 4, 141-148.

Greenfield, E. (1993, May). Evolution of the textbook: From print to multimedia. Technological Horizons in Education, pp. 12-19.

Houston, D. M. (1993). An exploration and analysis of the relationship among learning styles, teaching styles, gender and performance in a college computer science course (Doctoral dissertation, Kansas State University, 1994). Dissertation Abstracts International, 54, 2997A.

Howles, L., & Pettengill, C. (1993, June). Designing instructional multimedia presentations: A seven-step process. Technological Horizons in Education, pp. 58-61.

Imboden, H. H. (1985). The effects of computer enhanced instruction in teaching concepts of percent to low achieving college students (Doctoral dissertation, University of Missouri, 1985). Dissertation Abstracts International, 46, 10A.

Ingram, J. K. (1987). Implementing and assessing computer-augmented-teaching in the large lecture course (Doctoral dissertation, Northwestern University, 1987). Dissertation Abstracts International, 48, 11A.

Johnson, C. D. (1994). Computer-assisted, computer-based, and traditional instruction: Effects on developmental students' vocabulary knowledge. Research in Developmental Education, 11(4), 1-4.

Johnson, L., & Perez, S. (1996, May). Meeting the challenge: Final report of the computer-based developmental education project. Mission Viejo, CA: League for Innovation in the Community College.

Kemeny, J. G. (1991). Software for the classroom. Mathematics and Computer Education, 25(1), 33-37.

Khalili, A., & Shashaani, L. (1994). The effectiveness of computer applications: A meta-analysis. Journal of Research on Computing in Education, 27(1), 48-61.

Kiser, L. (1990, Fall). Interaction of spatial visualization with computer-enhanced and traditional presentations of linear absolute-value inequalities. The Journal of Computers in Mathematics and Science Teaching, 10(1), 85-96.

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

Kulik, J. A., Kulik, C. C., & Cohen, P. A. (1980). Effectiveness of computer-based college teaching: A meta-analysis of findings. Review of Educational Literature, 50(4), 525-544.

Lumsden, D. B. (1974). Individualizing instruction through the use of programmed instruction. The Educational Forum, 38(2),145-152.

Mayes, R. L (1995). The application of a computer algebra system as a tool in college algebra. School Science and Mathematics, 95(2), 61-68.

McGrath, D. (1994). An exploration and analysis of the relationship among learning styles, teaching styles, gender, and performance in a college computer science course (Doctoral dissertation, Kansas State University, 1993). Dissertation Abstracts International, 54, 8A.

Neter, J., & Chervany, N. (1973). Effects of use of computer in first-year statistics sequence on student attitudes. Decision Sciences, 4, 133-139.

Nygard, K. E., & Ranganathan, B. (1983). A system for generating instructional computer graphics. AEDS Journal, 16, 177-187.

Prybutok, V. R., Bajgier, S. M., & Atkinson, M. (1991). Statistics instruction: The next generation. The Journal of Computers in Mathematics and Science Teaching, 10(3), 15-27.

Schneider, K. C. (1977). Computer supported instruction in statistics: Long range implications. Decision Sciences, 8, 318-331.

Silberman, H. F. (1969). Applications of computers in education. In R. Atkinson and H. Wilson (Eds.), Computer-assisted instruction (pp. 49-61). New York: Academic Press.

Smith, D. A. (1982, Summer). Using computer graphics to teach mathematics. The Journal of Computers in Mathematics and Science Teaching, pp. 24-27.

Stockburger, D. W. (1982). Evaluation of three simulation exercises in an introductory statistics course. Contemporary Educational Psychology, 7, 365-370.

Super, J. (1993, January/February). Return on investment: Softening technology's up-front cost. Adult Learning, pp. 12-14.

Sutherland, R. (1993). Consciousness of the unknown. For the Learning of Mathematics, 13(1), 43-46.

Teles, E. J. (1991). Using the microcomputer to help students learn to interpret functional information. Mathematics and Computer Education, 25(3), 230-241.

Webster, E. (1992). Evaluation of computer software for teaching statistics. The Journal of Computers in Mathematics and Science Teaching, 11, 377-391.

Wiley, L. G. (1993). Relationships between teachers' attitudes, knowledge, and concerns about computers in education and a concerns-based approach to staff development. Dissertation Abstracts International, 54, 151A.

Willows, D. M., & Houghton, H. A. (1987). The psychology of illustration (Vol. 1). New York: Springer-Verlag.

Wilson, B. J. (1994). Technology and higher education: In search of progress in human learning. Educational Record, 75(3), 9-16.

Zimmermann, W., & Cunningham, S. (Eds.). (1991). Visualization in teaching and learning mathematics. Washington, DC: Mathematical Association of America (MAA).

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

Formative evaluation of the computer-based graphics presentation was done, in part, through a content review by a panel of experts during the spring 1996 semester. Students contributed to the evaluation of the graphics and clarity of the presentation through a pilot study conducted during the summer of 1996. All comments and suggestions were analyzed by the panel of experts, and changes in the presentation were completed prior to the summer II 1996 study.

The intent of this study was to examine the differences between the pretest and posttest performance of algebra students exposed to a computer-based graphics presentation on functions and graphing. Four class sessions were required for the data collection and the presentation, each session meeting in the morning for 2 hours, 4 days a week. This chapter describes the quantitative, quasi-experimental research methodology employed for the study. Included is a description of the target population, the presentation design, the research design, methods for gathering the data, the test instrument, the treatment, and the procedures for the analysis of the data.

Population of the Study

The population of Collin County Community College students taking intermediate algebra encompassed a cross-section of age and gender. Each class for this course registered approximately 20 students. Through assessment examinations, these students were placed at the intermediate algebra level. Community college students have been generally characterized as less academically prepared than students attending other institutions of higher education (Johnson & Perez, 1996).

All students from three intact classes of intermediate algebra at Collin County Community College during the summer semester of 1996 were involved in the study (n=51). There were 28 females and 23 males. There were 26 nontraditional age students and 25 traditional age (18-22 years) students. The typical registration procedure, class enrollment by student selection, was employed. It was assumed that the registration procedure resulted in a representative sample of the population. The sections were not chosen randomly from all scheduled sections so that all three sections were taught by the same instructor. Since this was a repeated measures design, each student served as his/her own control (Spatz & Johnston, 1976). This method was quasi-experimental since subjects were not randomly assigned to groups (Creswell, 1994).

Development of the Presentation Design

Introduction

The key to a successful presentation is the instructional design, regardless of whether the teaching medium is computerized or traditional lecture. Effective classroom teaching requires an acute awareness of the instructional principles for good teaching. The design and development of this computer-based graphics presentation followed the instructional design principles of Dick and Carey (1978); Gagne, Briggs, and Wager (1992); and the multimedia presentations process of Howles and Pettengill (1993). These principles of the instructional system were needs assessment or background information, goals, sequence of instruction, performance objectives, examples established, assessment, and an instructional delivery system or implementation plan. A detailed development of the instruction included Introduction, Rationale of Instruction, Instructional Goal, Description of Target Population, Instructional Design, Integration of the Software into the Curriculum, Instructional Strategy, Formative Evaluation, and Summative Evaluation. In this computerized presentation, careful attention was given to the objectives, finding appropriate software, and the reliable measurement of achievement of stated performance objectives. The multimedia design principles were select a topic conducive to multimedia enhancement, establish learning outcomes, create a scope and sequence outline, identify materials, explore multimedia techniques, develop a storyboard, and produce the lesson.

This computerized presentation introduced the topic of functions and graphing while concurrently addressing their real world applications. Techniques were presented in an effort to enable students to increase skill development in the area of functions and graphing. The primary mode of instruction was a computer-based graphics presentation (CBGP) supported by collaborative and participative learning.

The resources used to generate the module drew upon information from two distinct areas, resources relevant to the subject matter and resources relevant to the instructional process. Numerous books and articles contributed to the preliminary design with a formative evaluation of the presentation by a panel of experts who focused on the content and the presentation style. Further formative analysis was conducted by students during the summer 1996 semester who enrolled in two sections of intermediate algebra. Their focus was on the clarity of presentation and the graphics. The instructional content followed the standards of the National Council of Teachers of Mathematics (1989) and the general guidelines of Chipman and Segal (1985); DeMarois, McGowen, and Whitkanack (1996); Dubinsky and Harel (1992); Durant and Garofalo (1994); Hollowell and Duch (1991); Malik (1980); Leinhardt, Zaslavsky, and Stein (1990); Markovits, Eylon, and Bruckheimer (1986); and McKeague (1996). Graphical approaches to the presentation of the content were suggested by Alesandrini (1987); Bell and Janvier

(1981); Clement (1989); Karplus (1979); Kerslake (1977); Lillie, Hannum, and Stuck (1989); and Winn (1987).

Rationale of Instruction

Students need an understanding of functions and graphs in their preparation for advanced mathematics courses, referred to as calculus-readiness skills by the DTMS (Darken, 1995). This presentation was designed to address the cognitive components of learning, enabling the participants to comprehend the real world applicability of functions and graphs in a mathematics environment.

Instructional Goal

Three classes of intermediate algebra at Collin County Community College during the Summer II 1996 semester were introduced to this computerized presentation of functions and graphs. The students were given the Descriptive Test of Mathematics Skills for Functions and Graphs in a pretest attempt at assessment of their entry level mathematics knowledge in the area of functions and graphs. As a posttest, the students were again given the Descriptive Test of Mathematics Skills for Functions and Graphs in order to measure the change in students' levels of mathematics knowledge after exposure to the computerized presentation.

Instruction provided basic information on the fundamental techniques necessary for understanding functions and graphs. Collaborative learning was encouraged. This presentation was intended to achieve the mathematical competencies specified by the performance objectives through the strategic introduction of functions and graphs.

Instructional Design

Designed to help students understand functions and graphs, upon completion of this computer-enhanced instruction, students:

1. Identified their functions and graphing knowledge prior to instruction.

2. Identified the conceptual components of functions and graphs necessary for their success.

3. Applied function and graphing strategies.

4. Identified their functions and graphing knowledge after instruction.

There were 11 major units (see Appendix A), written in six individual sections of the computer program. Several units were combined on the computer since they instructionally used the same graphics and provided an excellent opportunity for comparison. Table 1 illustrates the relationship between the units and the computer presentation.

Table 1

A Comparison of the Instructional and Computer Unit

Instructional Unit	Computer Unit	Time Required (Minutes)	Objectives Covered
I. Relation and Function Awareness	Part 1	50	1-7
II. Function Machine	Part 2	15	8-10
III. Notation	Part 2	15	11-12
IV. Evaluating Functions	Part 2	35	13-15
V. Applications	Part 3	10	16-17
VI. Shapes	Part 4	50	18-26
VII. Vertical Line Test	Part 4	10	27-28
VIII. Linear Equations	Part 5	20	29-30
IX. Domain	Part 5	30	31-34
X. Range	Part 5	25	35-38
XI. Algebra of Functions	Part 6	40	39-42

During the development of this topic, an instructional analysis of the higher level skills revealed that 42 performance objectives were required for mastery of the instruction. (see Appendix A). Although some of the instruction was hierarchical, the movement from skill to skill showed a combinational methodology.

Integration of the Software into the Curriculum

Figure 1 is a visual description of the High-Level design for the functions and graphing module.

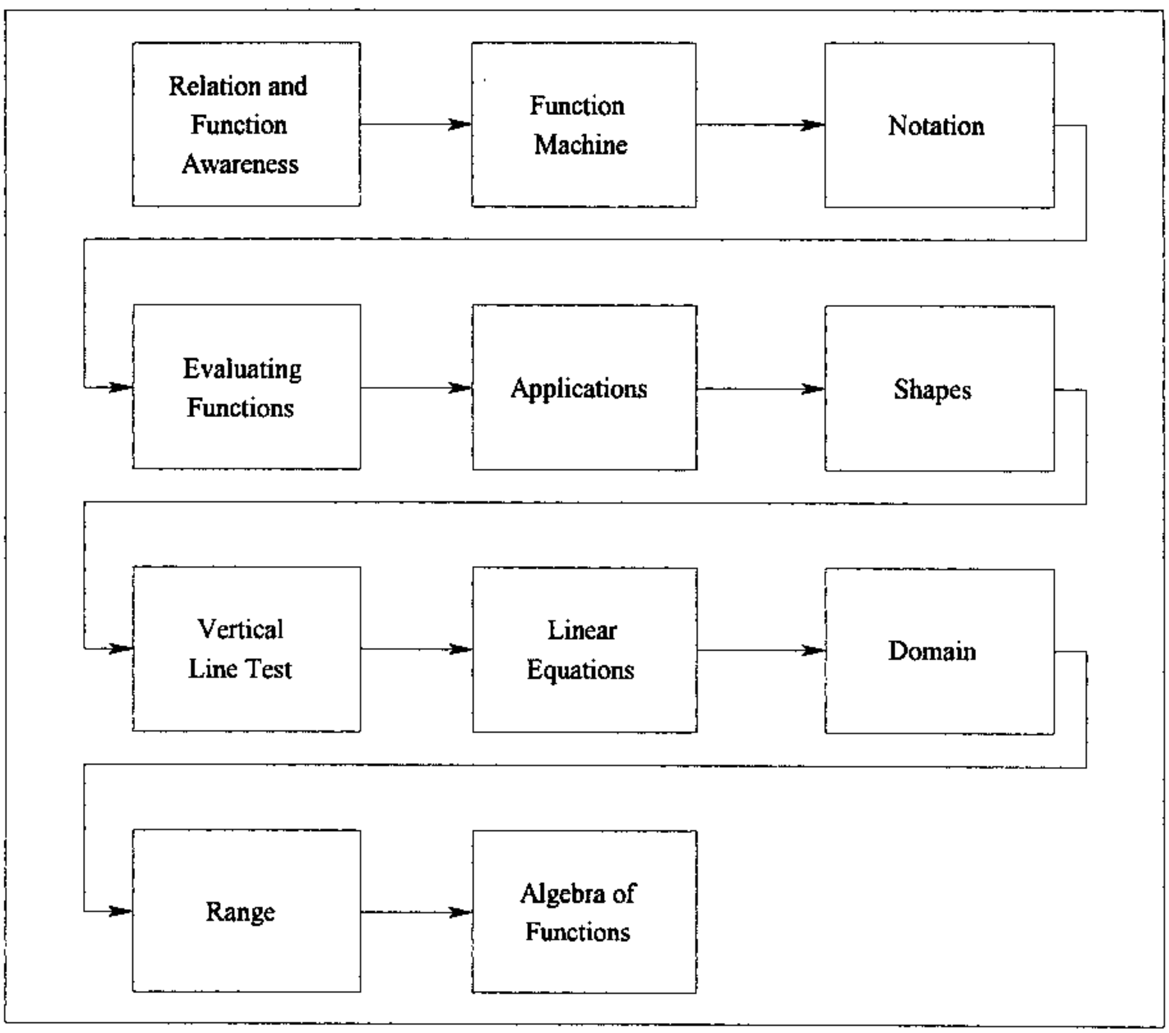

Figure 1. Topic Hierarchy for Functions and Graphing

Instructional Strategy

The instructional strategies described the general components of the instructional materials and indicated the procedures that were used with those materials. Each objective listed in the design section had a corresponding strategy for the attainment of that objective. Each strategy was divided into four components: preinstructional activity; formal instruction; any practice which was deemed beneficial for that objective; and finally, any follow-through activities.

The pre-instruction activity provided the motivation for learning the performance objective. It could have included a question which was answered during the instruction or may have included showing the students what they were able to do when they had completed the objective. The pre-instruction section also included a reiteration of the specific objective. The teacher should have emphasized the motivation here, since it set the tone for the rest of the objective.

The formal instruction was primarily in the form of a computerized presentation but could have included lecture, group discussion, or question and answer. Examples of required work were included wherever applicable.

The activity included forms of practice for the student with direct feedback from the instructor. Often included with the activity were embedded test items. Any embedded test items were for the exclusive purpose of formative evaluation and were to have been noted by the instructor for use in later revisions of the module.

The post-instruction was provided for the purpose of remediation or enrichment. These activities were to be utilized by the learners until or after mastery of the objective was obtained.

Each instructional strategy was illustrated by a table (see Figure 2). For each of the 42 instructional strategies, see Appendix B. The Instructional Sequencing strategy used the format shown in Figure 3. For the Instructional Sequencing strategy for this

INSTRUCTIONAL STRATEGY Topic No.__________

Enabling Objective No.__________

Pre-Instruction

Motivation	
Objective	

Instruction

Presentation	
Examples	
Embedded Tests	

Activity

Practice	
Feedback	

Post-Instruction

Remediation	
Enrichment	

Figure 2. Instructional Strategy Template

Objective number	Time Required	Lessons

Figure 3. Strategy Sequencing Template

unit, see Appendix C. After the instructional design was completed, a storyboard represented the separate slides for the conversion to a computer program. The presentation was divided into six units and was converted to a software package called Authorware for the Macintosh computer.

Formative Evaluation of the Treatment

The module was given to a panel of experts for the purposes of initial formative review. Participation by subject matter experts provided verification and modification of the following issues:

1. Comprehensive topics
2. Organizational clarity
3. Content accuracy
4. Appropriate objectives
5. Concept clarity
6. Visual appeal

In addition, embedded test items provided input for evaluation. Furthermore, a pilot group of two intermediate algebra classes during the summer of 1996 used the computerized presentation for feedback on the graphics and clarity of the instruction.

Research Design

This study examined the relationship between student performance and the use of computer-based graphics software as a mode of presentation in the teaching of functions and graphs. The experimental research design utilized for the study was a single-group design. Specifically, a one-group pretest-posttest design was used. The pretest was administered to measure the dependent variable, performance, followed by application of the treatment, computer-based graphics presentation (CBGP), followed by a posttest to measure the dependent variable again. A pretest was included to assess the knowledge of functions and graphs prior to the treatment. An ANOVA investigated for equivalence of the three classes of intermediate algebra chosen for this study.

The following research hypotheses were investigated:

1. There will be a significant difference between the pretest and posttest performance of students exposed to the computer-based graphics presentation.

2. There will be no significant difference between the pretest and posttest performance means of males and females exposed to the computer-based graphics presentation.

3. There will be no significant difference between the pretest and posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

To test the overall gain in pretest and posttest performance, a statistical analysis was conducted using a paired t-test, repeated measures design. For testing the second null hypothesis regarding gender, an independent t-test on the males' and females' pretest performance means was conducted followed by an independent t-test on their posttest means. The third hypothesis, based on age, was tested with an independent t-test on the traditional and nontraditional age students' pretest performance followed by an independent t-test on their posttest means. The level of significance was set at .01 to maintain an acceptable control over the Type I error that could result from multiple statistical tests.

Description of the Test Instrument

The student achievement measurement instrument for both the pretest and posttest data was the Descriptive Test of Mathematical Skills (DTMS) for Functions and Graphs with a reported reliability coefficient of .84 (College Entrance Examination Board, 1989c). Content validity was established through an equating study against pre-established written objectives. These tests were designed for several purposes, one of which was to "measure student performance upon completion of a program of instruction in mathematics." (College Entrance Examination Board, 1989b, p. 1). This test is a timed, 30-minute, multiple choice test with question clusters for detailed analysis of student knowledge of algebraic functions, exponential and logarithmic functions, and trigonometric functions. Each of these clusters has approximately 10 questions which can be analyzed separately for a diagnostic analysis of a student's strengths and weaknesses. The tests have been favorably reviewed by professionals in the field who have confirmed the test construction and supporting documentation (Dunbar, 1992; Hester, 1992).

Methods for Gathering the Data

All subjects received computer-based graphics instruction (CBGI) on functions and graphing by the same instructor, with the same objectives, and with the same instrumentation for measurement of scores. A pretest and posttest (Descriptive Test of Mathematical Skills for Functions and Graphs) was given to all groups. The instructor did not see the examination prior to the presentation to control for its possible influence on her teaching. The pretest was given on the first day of this unit. The students were given 30 minutes for the pretest. The computer-based presentation began after the pretest was completed. On the 4th day of presentation, the posttest was administered. Again, the posttest was a timed, 30-minute exam given on the last day of this unit. Students were asked to record answers to the pretest and posttest on scantrons. The pretest and posttest did not have a ceiling effect; that is, no students scored perfect marks.

The first alternative hypothesis was that the posttest performance means of the students exposed to the computer-based graphics presentation would be significantly higher than their pretest performance means. The means of the pretest and posttest scores for the CBGI groups were compared in order to provide evidence of an increase in student performance after exposure to this computer-based presentation. In addition, students were asked to record their gender and age range, 18-22 year olds or 23-older, so that the variables of gender and age could be investigated in terms of performance after exposure to CBGI.

Description of the Treatment

This computerized presentation introduced the topic of functions and graphing. The primary mode of instruction was a computer-based graphics presentation (CBGP) supported by collaborative and participative learning. The presentation used the software package Authorware for the Macintosh computer. Instruction was delivered via a television monitor and a computer monitor, each servicing a section of the room. Four class sessions, each of 2 hours duration, allowed for pretest, presentation, and posttest completion.

There were six sequenced components to the presentation material, with the following general topics: (a) mapping and the concept of function, (b) function notation and evaluation through a function machine, (c) applications and scientific exploration, (d) shapes and the vertical line test, (e) domain and range, and (f) the algebra of functions. The total time necessary for the pretest, presentation, and posttest was 6.5 hours using four class sessions. Instruction provided basic information on the fundamental techniques necessary for understanding functions and graphs. Collaborative learning was encouraged. This presentation was intended to achieve the mathematical competencies specified by the performance objectives through the strategic introduction of functions and graphs.

Procedure for Data Analysis

All data were organized in tables and histograms. Table 2 illustrates the organization of the raw data for all subjects. Table 3 shows how the descriptive data for all students were organized. From the data in these tables, histograms were then generated to visually compare pretest and posttest means. Scores, the dependent variable, was used as the y-axis label, and subjects served as the x-axis label.

Table 2

Raw Data for All Subjects

	Gender (M/F)	Age (T/N)	Pretest Score	Posttest Score
Subject 1				
Subject 2				
Subject 3				
.				
.				
.				
Subject ith				

Table 3

Descriptive Data of All Students

	Mean	Net Gain	Standard Deviation	Maximum/Minimum
Pretest				
Posttest				

The statistical analysis involved a t-test for correlated means using a repeated measures design. The dependent variable was interval level data. Homogeneity of variance was satisfied since the pretest and posttest data were collected on the same groups. There is no reason to suspect that the means of the groups were not normally distributed. The level of significance was set at .01. The first hypothesis tested was:

H_0: There will be no significant difference between the pretest and posttest performance means of students exposed to the computer-based graphics presentation.

H_a: The posttest performance mean of students exposed to the computer-based graphics presentation will be significantly higher than their pretest performance mean.

Table 4 illustrates how the data were tracked for the first hypothesis. Each student's posttest and pretest scores were recorded. The difference between each posttest and pretest score was calculated and labeled as *d*. The difference between *d* and the mean of *d* was calculated, $d - \bar{d}$. This difference was squared. This information was used to calculate the standard deviation of the difference scores using the formula $s_d = \sqrt{\frac{\sum (d - \bar{d})^2}{n - 1}}$. This value was then used to calculate the standard error of the differences using the formula $s_{\bar{d}} = \frac{s_d}{\sqrt{n}}$. These values were used for the t-test for correlated means to calculate $t = \frac{\bar{d} - \delta}{s_{\bar{d}}}$ (Hinkle, Wiersma, & Jurs, 1988). For this one-tailed test, α was set at .01, degrees of freedom were equal to n - 1, and the critical value of t was found in a table. If the computed t value exceeded the critical value, the null hypothesis was rejected, and the alternative hypothesis was accepted. If the computed t value did not exceed the critical value, the null hypothesis was retained.

Table 4

Calculated Data for the First Hypothesis

Subject	Posttest	Pretest	Gain (d)	$d - \bar{d}$	$(d - \bar{d})^2$
Student 1					
Student 2					
.					
.					
.					
Student i^{th}					

The second research hypothesis tested was:

H: There will be no significant difference between the pretest and posttest performance means of males and females exposed to the computer-based graphics presentation.

The hypothesis was considered in two separate cases, the pretest score comparisons and the posttest score comparisons. The first case hypothesis was:

H_0: There will be no significant difference between pretest performance means of males and females exposed to the computer-based graphics presentation.

H_a: There will be a significant difference between pretest performance means of males and females exposed to the computer-based graphics presentation.

The second case hypothesis was:

H_0: There will be no significant difference between posttest performance means of males and females exposed to the computer-based graphics presentation.

H_a: There will be a significant difference between posttest performance means of males and females exposed to the computer-based graphics presentation.

The third research hypothesis was:

H: There will be no significant difference between the pretest and posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

The hypothesis was considered in two separate cases, the pretest score comparisons and the posttest score comparisons. The first case hypothesis was:

H_0: There will be no significant difference between pretest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

H_a: There will be a significant difference between pretest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

The second case hypothesis was:

H_0: There will be no significant difference between posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

H_a: There will be a significant difference between posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

Each of these hypotheses was tested in a similar manner, and the data were recorded in a table (see Table 5 and Table 6) . Each investigation involved an independent two sample t-test, first comparing the pretest results and then comparing the posttest results on the basis of gender, followed by pretest and posttest comparisons by age. The variable of gender was examined by comparing the means of males to those of females. This involved the formulas $s = \sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}$ for calculating the standard deviation, $s_{\bar{X}-\bar{Y}} = \sqrt{s^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$ for the standard error of the difference between sample means and $t = \frac{\bar{X} - \bar{Y}}{s_{\bar{X}-\bar{Y}}}$ for the test statistic with $n_1 + n_2 - 2$ as the degrees of freedom. If the computed t value exceeded the critical value, the null hypothesis was rejected and the alternative hypothesis was accepted. If the computed t value did not exceed the critical value, the null hypothesis was retained.

The variable of age was investigated by comparing the means of traditional age students to those of nontraditional age students. This involved the same process and formulas as described above for the gender test. If the computed t value exceeded the critical value, the null hypothesis was rejected and the alternative hypothesis was accepted. If the computed t value did not exceed the critical value, the null hypothesis was retained.

Table 5

Independent t-test by Gender

Gender	Test Mean	Number of Subjects	t Value	df	Critical t Value
Males					
Females					

Table 6

Independent t-test for Posttest by Age

Age	Test Mean	Number of Subjects	t Value	df	Critical t Value
Traditional					
Nontraditional					

REFERENCES

Alesandrini, K. L. (1987). Computer graphics in learning and instruction. In D. Willows & H. Houghton (Eds.), The psychology of illustration (pp. 159-188). New York: Springer-Verlag.

Bell, A., & Janvier, C. (1981). The interpretation of graphs representing situations. For the Learning of Mathematics: an international journal of mathematics education, 2(1), 34-42.

Chipman, S. F., & Segal, J. W. (1985). Higher cognitive goals for education: An introduction. In S. F. Chipman & J. W. Segal (Eds.), Thinking and learning skills (pp. 1-19). Hillsdale, NJ: Erlbaum.

College Entrance Examination Board. (1989a). Descriptive test of mathematical skills for functions and graphs. New York: Author.

College Entrance Examination Board. (1989b). Descriptive tests of mathematical skills for functions and graphs: Instructor's guide. New York: Author.

College Entrance Examination Board. (1989c). Guide to the use of descriptive tests of mathematical skills. New York: Author.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage.

DeMarois, P., McGowen, M., & Whitkanack, D. (1996). Mathematical investigations: An introduction to algebraic thinking. New York: Harper Collins.

Dick, W., & Carey, L. (1978). The systematic design of instruction. Glenview, IL: Scott, Foresman and Company.

Dubinsky, E., & Harel, G. (Eds.). (1992). The concept of function: Aspects of epistemology and pedagogy. Washington, DC: Mathematical Association of America (MAA).

Dunbar, S. B. (1992). Descriptive tests of mathematics skills. In J. J. Kramer and J. C. Conoley (Eds.), The eleventh mental measurements yearbook (pp. 277-278). Lincoln, NE: University of Nebraska Press.

Durant, K., & Garofalo, J. (1994). Teaching functions and graphing in pre-calculus mathematics. The Journal of Developmental Education, 18(1), 18-24.

Gagne, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Orlando, FL: Harcourt Brace Jovanovich.

Hester, J. R. (1992). Descriptive tests of mathematics skills. In J. J. Kramer and J. C. Conoley (Eds.), The eleventh mental measurements yearbook (pp. 278-279). Lincoln, NE: University of Nebraska Press.

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1988). Applied statistics for the behavioral sciences (2nd ed). Boston: Houghton Mifflin.

Hollowell, K. A., & Duch, B. J. (1991, April). Functions and statistics with computers at the college level. Paper presented at the meeting of the Annual Conference of the American Educational Research Association, Chicago, IL.

Howles; L., & Pettengill, C. (1993, June). Designing instructional multimedia presentations: A seven-step process. Technological Horizons in Education, pp. 58-61.

Karplus, R. K. (1979). Continuous functions: Students' viewpoints. European Journal of Science Education, 1(4), 397-413.

Kerslake, D. (1977). The understanding of graphs. Mathematics in School, 6(2), 56-63.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. Review of Educational Research, 60(1), 1-64.

Lillie, D. L., Hannum, W. H., & Stuck, G. B. (1989). Computer and effective instruction. New York: Longman.

Lovell, K. (1970, October). Some aspects of the growth of the concept of a function. In M. F. Rosskipf, L. P. Steffe, & S. Taback (Eds.) Piagetian cognitive-development research and mathematical education (pp.12-33). Reston, VA: National Council of Teachers of Mathematics.

Malik, M. A. (1980). Historical and pedagogical aspects of the definition of function. International Journal of Mathematics Education and Science Technology, 11(4), 489-492.

Markovits, Z., Eylon, B., & Bruckheimer, M. (1986). Functions today and yesterday. For the Learning of Mathematics, 6(2), 18-28.

McKeague, C. H. (1996). Functions & graphs. Orlando, FL: Harcourt Brace.

National Council of Teachers of Mathematics (NCTM). (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: Author.

Spatz, C., & Johnston, J. O. (1976). Basic statistics: Tales of distributions. Monteray, CA: Brooks/Cole.

Winn, B. (1987). Charts, graphs, and diagrams in educational materials. In D. Willows & H. Houghton (Eds.), The psychology of illustration (pp. 168-198). New York: Springer-Verlag.

CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

The purpose of this chapter is to present the data collected from a study conducted at Collin County Community College. All students from three intact classes of intermediate algebra were involved in the study (n=51). There were 28 females and 23 males. There were 25 nontraditional age students and 26 traditional age (18-22 years) students. The typical registration procedure, via class enrollment by student selection, was employed. It was assumed that the registration procedure resulted in a representative sample of the population. The sections were not chosen randomly from all scheduled sections so that all three sections were morning classes which were offered four days a week and were taught by the same instructor. This was a repeated measures design where each student served as his/her own control (Spatz & Johnston, 1976). This method was quasi-experimental since subjects were not randomly assigned to groups (Creswell, 1994). A single group pretest/posttest design was used. Research was conducted to analyze the difference between pretest and posttest performance means after exposure to a computer-based graphics presentation. Data was also investigated for possible gender and age differences.

Table 7 lists the raw data for the 51 subjects. Gender, recorded as M or F, represented male or female, respectively. Age, recorded as T or N, represented traditional age or nontraditional age students, respectively. The pretest and posttest did not have a ceiling effect; that is, no students scored perfect marks.

Table 7

Raw Scores on All Subjects

Subject	Gender (M/F)	Age (T/N)	Pretest Score	Posttest Score	Group
1	F	T	3	18	1
2	F	N	3	12	1
3	M	T	9	11	1
4	M	T	0	9	1
5	F	N	0	15	1
6	M	T	9	15	1
7	M	N	0	9	1
8	F	N	3	6	1
9	F	T	15	24	1
10	F	N	3	6	1
11	M	N	3	18	1
12	M	N	9	12	1
13	F	T	6	13	1
14	F	N	11	14	1
15	M	T	7	7	1
16	F	N	8	9	1
17	M	N	6	16	1
18	F	N	4	13	1
19	F	T	21	24	2
20	M	T	5	19	2
21	F	N	5	18	2
22	F	T	11	22	2
23	M	T	3	10	2
24	F	N	19	19	2
25	F	T	2	8	2
26	M	T	10	15	2
27	M	N	9	17	2
28	M	T	10	15	2
29	F	N	11	18	2
30	F	N	12	15	2
31	M	T	12	12	2
32	M	N	15	21	2
33	F	N	0	3	2
34	F	T	1	12	2
35	M	T	6	15	2
36	M	T	6	9	3
37	M	N	4	22	3
38	F	N	9	16	3
39	M	N	2	17	3
40	M	N	6	13	3
41	F	T	1	14	3

(table continues)

Subject	Gender (M/F)	Age (T/N)	Pretest Score	Posttest Score	Group
42	F	N	9	15	3
43	F	T	11	19	3
44	M	T	4	4	3
45	F	N	1	12	3
46	F	T	11	21	3
47	M	N	2	3	3
48	M	T	6	15	3
49	F	T	3	5	3
50	F	T	0	6	3
51	F	T	9	21	3

Procedure for Data Analysis

Because all classes were taught by the same instructor, meeting the same number of days a week, and all were morning classes, there was no reason to suspect that all three groups initially differed in nonrandom factors. As a precaution, however, a one-way ANOVA on the pretest was run to identify any nonrandom factor that would have prohibited putting classes together as a single group for analysis purposes (see Table 8).

Table 8

One-way ANOVA for Pretest Scores for All Subjects by Group

Source	df	Sum of Squares	Mean of Squares	F Ratio	F Critical Value
Between	2	144.0686	72.0343	3.2241	5.08
Within	48	1,072.4412	22.3425		
Total	50	1,216.5098			

The following hypothesis was tested:

H_0: There is no significant difference on the pretest performance means of the three groups.

H_1: There is a significant difference on the pretest performance means of the three groups.

The data for this hypothesis were not statistically significant at the .01 level, $F_{crit}(2, 48) = 5.08$, and the null hypothesis was retained. No two groups were significantly different, and the groups were, therefore, combined for all subsequent statistical examinations.

The histogram in Figure 4 illustrates the relationship among the three groups pretest and posttest performance means. Although Group 2 did have a higher pretest mean than Group 1 or Group 3, it was not significantly higher than the other groups.

The descriptive statistics for all students indicated a gain in the overall posttest mean (see Table 9). The group posttest mean was considerably higher than the group pretest mean. The raw score gain was 7.215, representing a 109.8% gain. An inferential statistical procedure, a paired t-test, one-tailed, was employed to test for statistical significance of this gain.

The first research hypothesis tested was:

H_0: There is no significant difference between the pretest and posttest performance means of students exposed to the computer-based graphics presentation.

H_a: The posttest performance mean of students exposed to the computer-based graphics presentation is significantly higher than their pretest performance mean.

Figure 4. Pretest/Posttest Comparisons of Group Means

Table 9

Descriptive Data for All Students

Test	Mean	Net Gain	Standard Deviation	Minimum/ Maximum
Pretest	6.569		4.933	0 - 21
Posttest	13.784	+7.215	5.456	3 - 24

Statistical analysis involved a t-test for correlated means since each subject's pretest score was correlated with their posttest score (see Table 10). The paired t-test measured whether the gain in student performance on the Descriptive Test of Mathematical Skills (Functions and Graphs) was statistically significant. The level of significance was set at .01. Since the data for this hypothesis were statistically significant at the .01 level, $t_{crit}(50) = 2.423$, $(p < .01)$ for a one-tailed test, the null hypothesis was rejected and the alternative hypothesis was accepted. Therefore, the posttest performance of students exposed to the computer-based graphics presentation was significantly higher than their pretest performance. The histogram in Figure 5 illustrates the relationship among all subjects' pretest and posttest scores.

Table 10

Paired t-test for All Subjects

Subject	Posttest Mean	Pretest Mean	Mean Gain	t Value	df	p Value
All students	13.7843	6.5686	7.2157	11.16	50	.000

After the analysis to determine that a significant difference existed between the pretest and posttest scores, further investigation was conducted by gender and age. The second research hypothesis was:

H: There will be no significant difference between the pretest and posttest performance means of males and females exposed to the computer-based graphics presentation.

This hypothesis was considered in two separate cases, the pretest score comparisons and the posttest score comparisons. The first case hypothesis was:

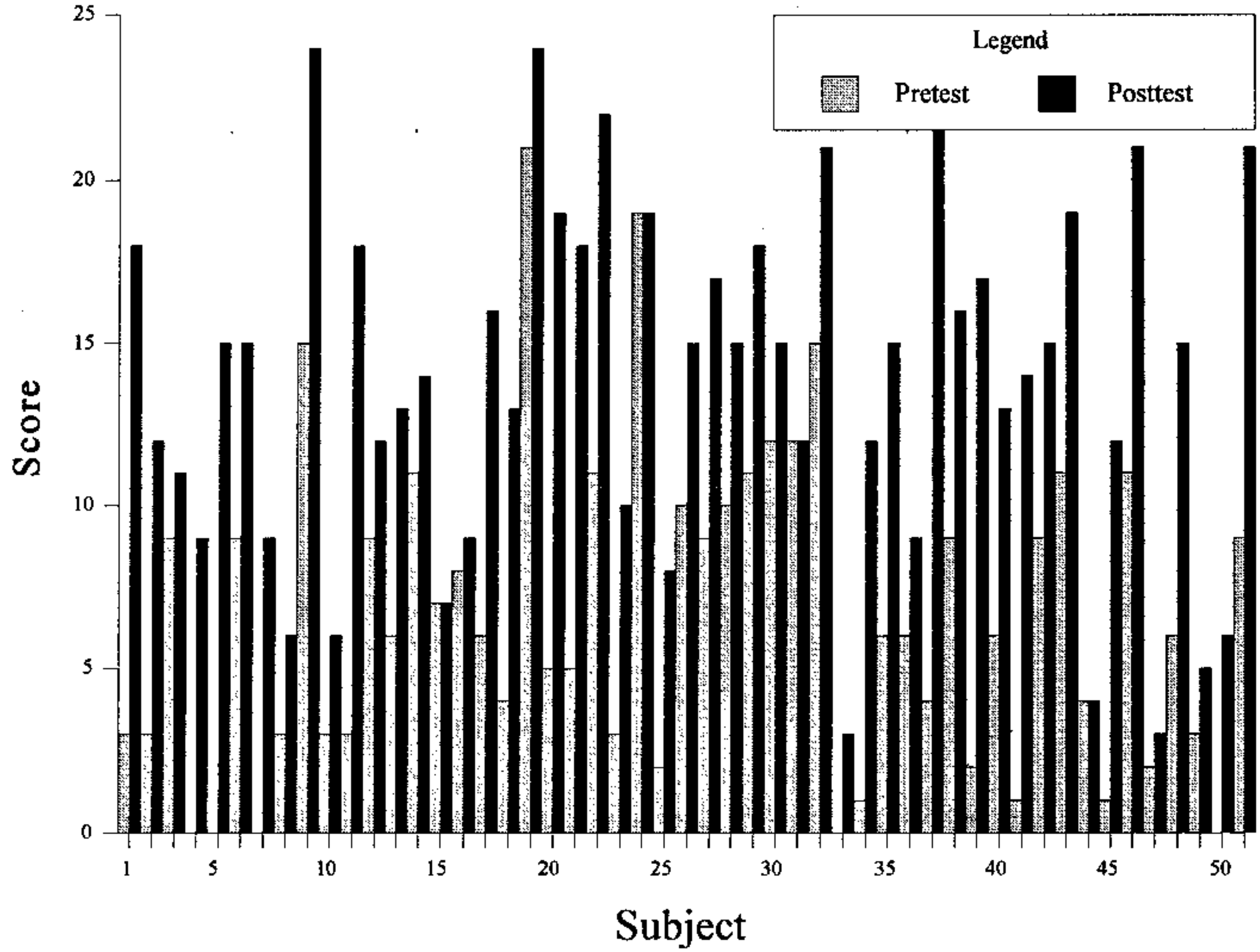

Figure 5. Pretest/Posttest Comparisons for all Subjects

H_0: There is no significant difference between the pretest performance means of males and females exposed to the computer-based graphics presentation.

H_a: There is a significant difference between the pretest performance means of males and females exposed to the computer-based graphics presentation.

The analysis of the first case hypothesis was done by an independent t-test on the pretest scores of males and females. The test was independent since the scores were not paired. The data for the first case hypothesis were not statistically significant at the .01 level, $t_{crit}(49) = 2.704$, ($p > .01$) for a two-tailed test, and the null hypothesis was retained. Therefore, there was no significant difference between the pretest performance means of males and females exposed to the computer-based graphics presentation (see Table 11).

Table 11

Independent t-test for Pretest by Gender

Gender	Mean Score/ Pretest	Mean Gain Score	t Value	df	p Value
Males	6.5652	.0062	.00	49	.996
Females	6.5714				

The second case analysis was to determine if a significant difference existed on the posttest scores on the basis of gender. The second case hypothesis was tested with an independent t-test on the posttest scores:

H_0: There is no significant difference between the posttest performance means of males and females exposed to the computer-based graphics presentation.

H_a: There is a significant difference between the posttest performance means of males and females exposed to the computer-based graphics presentation.

Since data from the second case hypothesis were not statistically significant at the .01 level, $t_{crit}(49) = 2.704$, $(p > .01)$ for a two-tailed test, the null hypothesis was retained. Therefore, there was no significant difference between the posttest performances of males and females exposed to the computer-based graphics presentation (see Table 12).

Table 12

Independent t-test for Posttest by Gender

Gender	Posttest Means	Mean Gain	t Value	df	p Value
Males	13.8696	.1553	.10	49	.921
Females	13.7143				

Overall, there was no statistically significant relationship between gender and performance means after exposure to CBGP. This was not surprising since the teacher, not the students, manipulated the technology. The percentage gain for females was 110.5% and for males was 111.3%. The histogram in Figure 6 illustrates the relationship between the pretest and posttest performance by gender.

The third research hypothesis was:

H: There will be no significant difference between the pretest and posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

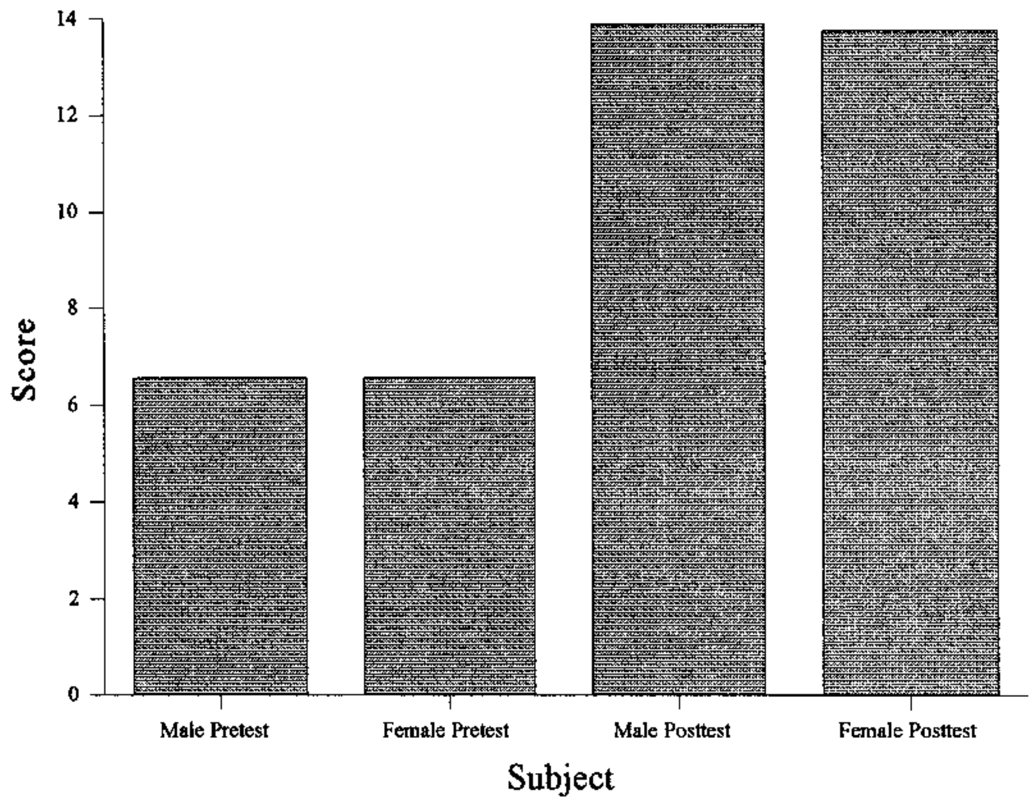

Figure 6. Pretest/Posttest Comparisons by Gender

This hypothesis was considered in two separate cases, the pretest score comparisons and the posttest score comparisons. The first case hypothesis was:

H_0: There is no significant difference between the pretest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

H_a: There will be a significant difference between the pretest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

The analysis for the first case hypothesis was an independent t-test because the scores were not paired. Since the data were not statistically significant at the .01 level, t_{crit} (49) = 2.704, (p > .01) for a two-tailed test, the null hypothesis was retained. Therefore, there was no significant difference between the pretest performances of traditional and nontraditional age students exposed to the computer-based graphics presentation (see Table 13).

Table 13

Independent t-test for Pretest by Age

Age	Mean Score/ Pretest	Mean Gain Score	t Value	df	p Value
Nontraditional	6.1600	.8015	.58	49	.567
Traditional	6.9615				

The analysis of the second case hypothesis was to determine if a significant difference existed on the posttest scores on the basis of age. The following hypothesis was tested with an independent t-test on the posttest scores:

H_0: There is no significant difference between the posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

H_a: There is a significant difference between the posttest performance means of traditional and nontraditional age students exposed to the computer-based graphics presentation.

Since the data for the second case hypothesis were not significant at the .01 level, t_{crit} (49) = 2.704, (p > .01) for a two-tailed test, the null hypothesis was retained.

Therefore, there was no significant difference between the posttest performances of traditional and nontraditional age students exposed to the computer-based graphics presentation (see Table 14).

Table 14

Independent t-test for Posttest by Age

Age	Posttest Mean	Mean Gain	t Value	df	p Value
Nontraditional	14.0000	.4400	.29	49	.777
Traditional	13.5600				

Overall, there was no statistically significant relationship between traditional and nontraditional age student performance means after exposure to CBGP. The percentage gain for traditional age students was 101.1% and for nontraditional age students was 120.1%. The histogram in Figure 7 illustrates the relationship between the pretest and posttest performance by age.

There are several interesting points to consider. First, the instructor did not see the pretest/posttest examination until after the experiment concluded. She was given the performance objectives only. This prevented her from teaching to the test. Second, it is important to note that there was inadequate control of what students did between classroom sessions on the topic of functions and graphing. Various study times and productivity of homework sessions could have influenced the test performance. Third, the exams tested short-term performance objectives. This is only one, although important, aspect of the learning process.

In summary, the posttest means were significantly higher than the pretest means after exposure to the computer-based graphics presentation. No significant difference in posttest means were found, however, on the basis of gender or age.

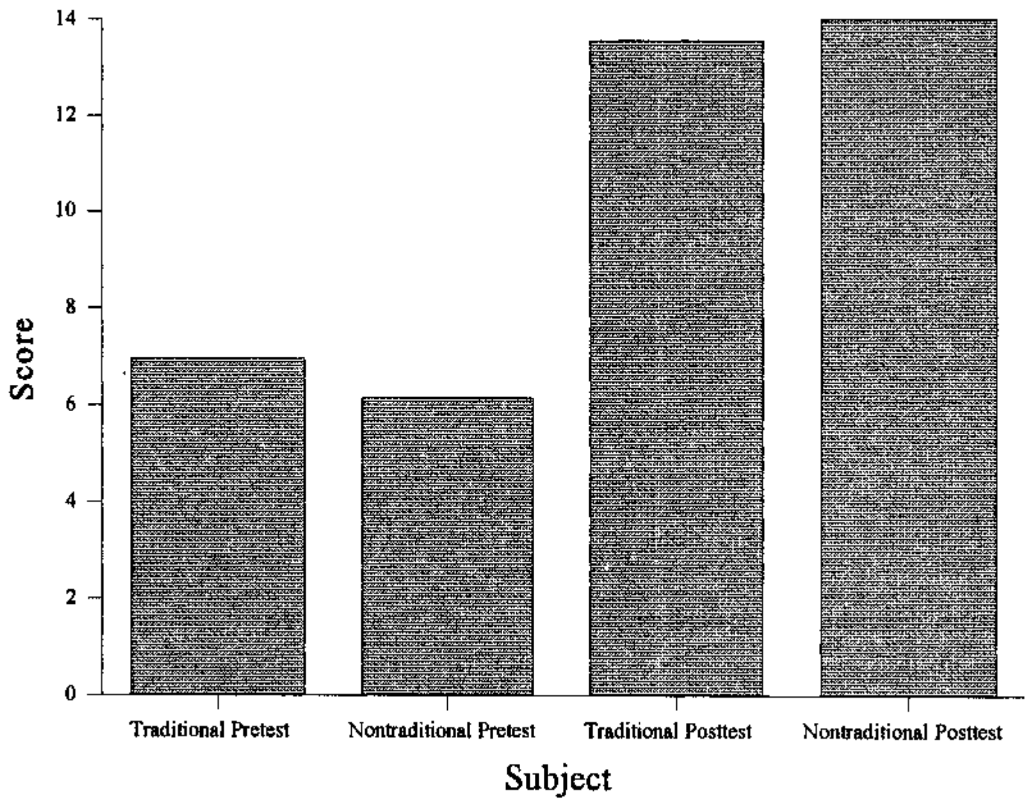

Figure 7. Pretest/Posttest Comparisons by Age

REFERENCES

Borg, W. R., & Gall, M. D. (1989). Educational research (5th ed.). New York: Longman.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage.

Spatz, C., & Johnston, J. O. (1976). Basic statistics: Tales of distributions. Monteray, CA: Brooks/Cole.

CHAPTER 5

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter provides a brief summary of the findings, conclusions drawn from the findings, and recommendations for future research.

Summary

The purposes of this study were to: (a) design a computer-based graphics presentation for the teaching of functions and graphs; (b) develop the computer-based graphics presentation; and (c) implement the presentation, measuring subsequent changes in student performance. The design and development of this computer-based graphics presentation followed the instructional design principles of Dick and Carey (1978); Gagne, Briggs, and Wager (1992); and the multimedia presentations process of Howles and Pettengill (1993). The principles of the instructional system were needs assessment or background information, goals, sequence of instruction, performance objectives, examples established, assessment, and an instructional delivery system or implementation plan. The multimedia design principles were to select a topic conducive to multimedia enhancement, establish learning outcomes, create a scope and sequence outline, identify materials, explore multimedia techniques, develop a storyboard, and produce the lesson.

This computerized presentation introduced the topic of functions and graphing. The presentation used the software package Authorware for the Macintosh computer. Instruction was delivered via a television monitor and a computer monitor, each servicing a section of the room. Four class sessions, each of 2 hours duration, allowed for pretest, presentation, and posttest completion.

All students from three intact classes of intermediate algebra at Collin County Community College were involved in the study (n=51). There were 28 females and 23 males. There were 25 nontraditional age students and 26 traditional age students (18-22 years). The typical registration procedure, via class enrollment by student selection, was employed. It was assumed that the registration procedure resulted in a representative sample of the population. The sections were not chosen randomly from all scheduled sections so that all three sections were taught by the same instructor and met twice a week in the morning. Since this was a repeated measures design, each student served as his/her own control (Spatz & Johnston, 1976). This method was quasi-experimental since subjects were not randomly assigned to groups (Creswell, 1994).

All subjects received a computer-based graphics presentation (CBGP) on functions and graphing by the same instructor, with the same objectives, and with the same instrumentation for measurement of scores. A pretest and posttest, Descriptive Test of Mathematical Skills for Functions and Graphs (DTMS), was given to all groups with a reported reliability of .84 and established content validity. The pretest was given on the first day of this unit. The students were given 30 minutes for the pretest. The computer-based presentation began after the pretest was completed. On the 4th day of presentation, the posttest was administered. Again, the posttest was a timed, 30-minute exam, given on the last day of this unit. Students were asked to record answers to the pretest and posttest on scantrons. The pretest and posttest did not have a ceiling effect; that is, no students scored perfect marks.

The quasi-experimental research design utilized for the study was a single-group design. Specifically, a one-group pretest-posttest design was used, typical in classroom research. The pretest was administered to measure the dependent variable, performance, followed by application of the treatment, computer-based graphics presentation (CBGP), followed by a posttest to measure the dependent variable again. A pretest was included to assess the knowledge of functions and graphs prior to the treatment. The statistical analysis on the pretest/posttest gain was a t-test for correlated means, repeated measures design. Additional analyses were conducted through two independent t-tests to investigate gender and age differences.

The review of the literature indicated that billions of dollars are being spent on technology. Instructors have gone beyond computer-assisted instruction and now use the computer as a presentation tool, yet few teachers are measuring the net gain in student performance. This could be explained by the fact that instructors are under tremendous time constraints. The added time for pretest and posttest measurements can be prohibitive. In today's society of increased pressure for accountability, this process may not be an option. The analyses supported that a significant difference existed between the pretest and posttest scores of students exposed to this computer-based presentation but found no significant differences with regard to gender and age.

Findings

The data from this study provide for the following findings:

1. There was a significant difference between the pretest and posttest performance of students exposed to the computer-based graphics presentation.

2. There was no significant gender difference between the pretest and posttest performance after exposure to the computer-based graphics presentation.

3. There was no significant difference between the pretest and posttest performance of traditional and nontraditional age students exposed to the computer-based graphics presentation.

Although studies have been done in computer-assisted instruction that indicated that there were performance differences on the basis of gender, no differences were found in this study. With computer-based instruction, the student does not manipulate the technology, thus reducing the possibility of gender interaction. Age also did not prove to be a significant factor in test performance. In summary, there was a significant gain in posttest scores after students received the computerized instruction regardless of gender or age.

Conclusions

Using the computer as a classroom teaching tool is a relatively new paradigm investigated in this study. The generalizability of the findings, however, needs to be done cautiously, due to the delimitations of the study. The research results were dependent both on the particular presentation developed as well as the instrumentation, the Descriptive Test of Mathematics Skills for Functions and Graphing.

The findings from this study support the following conclusions:

1. Computer-based instruction can increase mathematics achievement among community college intermediate algebra students.

2. Mathematics achievement of community college intermediate algebra students exposed to computer-based instruction is not dependent on gender.

3. Performance results from computer-based instruction for community college intermediate algebra students is not dependent on age.

In summary, computer-based graphics instruction was a viable technique for increasing mathematics performance.

Recommendations

The following suggestions are made to educational constituents for improved pedagogical implementation of computer technology.

Teachers need to:

1. Attend staff development classes on technology. This will increase understanding of the computer's instructional capabilities.

2. Listen to student reaction to the technology. Not all students will respond in the same way. Awareness of learning style differences can influence decisions on how to present the various mathematical concepts.

3. Select computer applications carefully. Not all topics can be enhanced through the use of a computer.

Administrators need to:

1. Provide and encourage faculty development opportunities on technology. Faculty need to be given the time to pursue this new paradigm.

2. Support faculty research on the impact of computerized presentations.

Publishers should:

1. Hire curriculum development specialists in the field to develop software for classroom use.

2. Listen to faculty and what they need.

3. Listen to students and what they need.

Textbook selection committees should:

1. Evaluate software supplements.

2. Demand supplements designed with sound instructional and multimedia principles (Dallal, 1988).

Recommendations for research on the topic of computer-enhanced instruction are based on the remarks of professionals in the literature as well as the data from this study. Variables other than gender and age may be relevant in the study of classroom pedagogy.

The instructor of this presentation observed an increased sophistication in student questions and responses coupled with increased interest. The instructor also observed that the objectives were covered in less time than she would have spent lecturing. These observations warrant further investigation.

Other factors that may be affected through the use of microcomputers in the classroom could be considered for future research:

1. Does CBGI affect attitudinal changes in students? A sensitive instrument could be administered in a similar pretest/posttest design. The attitudinal changes could be general in nature toward the subject or specific toward the topic. Changes in attitude about computers or specifically computers in the classroom could also be measured.

2. Does the use of CBGI increase long-term retention of mathematical concepts? Longitudinal studies are one method of investigating long-term retention of mathematical concepts. Success in subsequent courses could be tracked.

3. Does the students' prior computer knowledge influence the effectiveness of CBGI in mathematics? Computer anxiety as well as prior computer knowledge could be measured and tested for possible interactions with performance results after exposure to computer presentations. In addition, gender issues could be critical in computer research.

4. Do the individual learning styles of students change the effectiveness of CBGI? Learning style assessments could be given prior to the treatment and compared with student performance.

5. Does a student's spatial visualization ability predict success for CBGI? Spatial visualization measurements could be taken prior to the treatment and compared with student performance.

6. Does CBGI affect retention? At the end of the semester, comparisons could be made between the net gain from the pretest and posttest and retention.

7. Is CBGI cost effective? A cost analysis could be performed on the benefits of using CBGI and its associated cost, including low-level and high-level performance objectives.

A further recommendation is made that other instruments be developed and used to assess changes in student performance beyond the measurement of low-level performance objectives. Numerous variables are involved in the measurement of cognitive achievement. New methods for measuring student outcome of higher order thinking skills must be studied. Continued research in the area of computer-based instruction could provide evidence and support for administrative decisions about technological development within an institution of higher learning.

REFERENCES

College Entrance Examination Board. (1989a). Descriptive test of mathematical skills for functions and graphs. New York: Author.

College Entrance Examination Board. (1989b). Descriptive tests of mathematical skills for functions and graphs: Instructor's guide. New York: Author.

College Entrance Examination Board. (1989c). Guide to the use of descriptive tests of mathematical skills. New York: Author.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage.

Dallal, G. E. (1988). Statistical microcomputing--like it is. The American Statistician, 42(3), 212-216.

Dick, W., & Carey, L. (1978). The systematic design of instruction. Glenview, IL: Scott, Foresman and Company.

Gagne, R. M., & Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Orlando, FL: Harcourt Brace Jovanovich.

Howles, L., & Pettengill, C. (1993, June). Designing instructional multimedia presentations: A seven-step process. Technological Horizons in Education, pp. 58-61.

Spatz, C., & Johnston, J. O. (1976). Basic statistics: Tales of distributions. Monteray, CA: Brooks/Cole.

APPENDIX A

PERFORMANCE OBJECTIVES

PERFORMANCE OBJECTIVES

UNIT I: Relation and Function Awareness
Increase self-awareness of the concept of mathematical relations and functions.
During this unit, students will:

1. Define a relation and a function using Webster's dictionary.
2. Write examples of mathematical relations.
3. List common real world relations.
4. List common real world functions.
5. Draw relations using a mapping between sets.
6. Draw functions using a mapping between sets.
7. Identify, compare, and contrast relations and functions.

UNIT II: Function Machine
Demonstrates visualization of functions through use of a function machine.
During this unit, students will:

8. Utilize a function machine to identify input of a function.
9. Utilize a function machine to identify output of a function.
10. Describe the "visualization" technique using an example.

UNIT III: Notation
Understands how f(x) is used in the notation of a function.
During this unit, students will:

11. Identify the effects of f(x) on an equation.
12. Discuss the appropriateness of using f(x) or y notation.

UNIT IV: Evaluating Functions
Evaluates functions at specified input values.
During this unit, students will:

13. Write the steps in the evaluation of a function using color coding for the input value.
14. Write a mathematical procedure for evaluating functions paralleled in "words" and "symbols".
15. Form ordered pair relationships described by f(x).

UNIT V: Applications
Understands relations and functions as they occur in the real world.
During this unit, students will:

16. Identify the relationship between weekly wages and hourly wage.
17. State examples of linear and cubic functions in the real world.

UNIT VI: Shapes

Applies knowledge of general geometric shapes to algebraic equations.
During this unit, students will:

18. Discuss patterns of algebraic equations.
19. Identify the "shape" of a linear function.
20. Identify the "shape" of a quadratic function.
21. Identify the "shape" of a cubic function.
22. Identify the "shape" of a logarithmic function.
23. Identify the "shape" of an absolute value function.
24. Identify the "shape" of a exponential function.
25. Identify the "shape" of a rational function.
26. Identify the "shape" of a square root function.

UNIT VII: Vertical line test

Apply a geometric test. to the graph of a relation.
During this unit, students will:

27. Identify a function when given the graph.
28. Identify a relation when given the graph.

UNIT VIII: Linear Equations

Graphs linear equations.
During this unit, students will:

29. Use anthropometry to study a real world linear equation.
30. Graph linear equations with split-plot.

UNIT IX: Domain

Applies function machine strategies to the domain of a function.
During this unit, students will:

31. Compare the input of the function machine to the domain.
32. Use the graph on a Cartesian plane to identify the domain.
33. Write the domain from the algebraic equation.
34. List the general restrictions on the domain of a function.

UNIT X: Range

Applies function machine strategies to the range of a function.
During this unit, students will:

35. Compare the output of the function machine to the range.
36. Use the graph on a Cartesian plane to identify the range.
37. Write the range from the algebraic equation.
38. List the general restrictions on the range of a function.

UNIT XI: Algebra of Functions

Applies evaluation of functions techniques to the algebra of functions.

During this unit, students will:

39. Discuss the four operations: addition, subtraction, multiplication, and division as they relate to functions.
40. Use the function notation for addition, subtraction, multiplication, and division of functions.
41. Algebraically find the sum, difference, product, and quotient of functions.
42. Geometrically demonstrate the addition, subtraction, multiplication, and division of functions.

APPENDIX B

INSTRUCTIONAL STRATEGY

INSTRUCTIONAL STRATEGY

Topic No. I

Enabling Objective No. 1

Pre-Instruction

Motivation	Computer enhanced instruction.
Objective	Determine student function and graphing knowledge.

Instruction

Presentation	Give the pretest.
Examples	Standardized math test, Descriptive Test of Mathematics Skills.
Embedded Tests	None. The pretest serves as the test.

Activity

Practice	Students complete the pretest.
Feedback	Tally the results.

Post-Instruction

Remediation	Additional assessments as needed.
Enrichment	Provide references for additional reading.

INSTRUCTIONAL STRATEGY Topic No. 1

Enabling Objective No. 2

Pre-Instruction

Motivation	Increased self-awareness of pre-calculus readiness.
Objective	Define a relation and a function.

Instruction

Presentation	Use Webster's dictionary to define relation. Use Webster's dictionary to define function.
Examples	Discuss the terms relation and function.
Embedded Tests	Write in your own words the meaning of relation and function.

Activity

Practice	Examples in section 3.3.
Feedback	Respond to questions. Cooperative learning techniques will assisst in concept building.

Post-Instruction

Remediation	Homework problems from section 3.3.
Enrichment	Have students write their own examples of relation and function.

INSTRUCTIONAL STRATEGY

Topic No. I

Enabling Objective No. 3

Pre-Instruction

Motivation	Increased understanding of the real world occurences of the mathematical concept of relations.
Objective	Write examples of mathematical relations, including real world relations.

Instruction

Presentation	Present the symbols =, <, ≥.
Examples	$y = x$; $y < x^2$; $y > x^3 - 5$.
Embedded Tests	What are other common relations associated with mathematics?

Activity

Practice	Group discussion of the common relations. Discuss student experiences.
Feedback	Respond to comments or questions.

Post-Instruction

Remediation	Class discussion.
Enrichment	Additional readings.

INSTRUCTIONAL STRATEGY Topic No. I

Enabling Objective No. 4

Pre-Instruction

Motivation	Share my National Association of Developmental Educators conference presentation on math anxiety.
Objective	List common real world functions.

Instruction

Presentation	Discuss functions.
Examples	Linear, logarithmic, exponential, Quadratic, and Cubic functions will be cited.
Embedded Tests	State five examples of functions or relations.

Activity

Practice	Each student will contribute one journal or newspaper article or internet search results that used a relation or a function example.
Feedback	Interactive responses.

Post-Instruction

Remediation	Additional journal or newspaper articles or Internet results.
Enrichment	Additional journal or newspaper articles or Internet results.

INSTRUCTIONAL STRATEGY Topic No. I

Enabling Objective No. 5

Pre-Instruction

Motivation	Visual depiction of an abstract concept.
Objective	Draw relations using a mapping between sets.

Instruction

Presentation	Guided question and answer session on mappings of relations.
Examples	Mapping of students with phone numbers.
Embedded Tests	Map two examples of relations.

Activity

Practice	Classroom discussion.
Feedback	Instructor responses.

Post-Instruction

Remediation	Math lab assistance.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. I

Enabling Objective No. 6

Pre-Instruction

Motivation	Visual depiction of an abstract concept.
Objective	Draw functions using a mapping between sets.

Instruction

Presentation	Guided question and answer session on mappings of functions.
Examples	Students with chairs.
Embedded Tests	Map two examples of functions.

Activity

Practice	Classroom discussion.
Feedback	Instructor responses.

Post-Instruction

Remediation	Math lab assistance.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. I

Enabling Objective No. 7

Pre-Instruction

Motivation	Salary example.
Objective	Identify, compare, and contrast relations and functions.

Instruction

Presentation	Discussion of the criteria for functions.
Examples	"Is a brother of." "Weekly salary."
Embedded Tests	Give an example of a relation. Determine whether it is a function.

Activity

Practice	On-task conversation.
Feedback	Provide responses to questions.

Post-Instruction

Remediation	Give examples of "evaluation." Individual conferences.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. II

Enabling Objective No. 8

Pre-Instruction

Motivation	Visualization.
Objective	Utilize a function machine to identify input of a function.

Instruction

Presentation	Use a function machine to help the student visualize input.
Examples	The relationship between number of hours worked and weekly salary.
Embedded Tests	List possible inputs.

Activity

Practice	Each student examines the function machine inputing various number of hours worked.
Feedback	Respond to questions about the results.

Post-Instruction

Remediation	Additional homework exercises.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. II

Enabling Objective No. 9

Pre-Instruction

Motivation	Visualization.
Objective	Utilize a function machine to identify output of a function.

Instruction

Presentation	Use a function machine to help the student visualize output.
Examples	The relationship between number of hours worked and weekly salary.
Embedded Tests	List possible outputs.

Activity

Practice	Each student examines the function machine output resulting from various number of hours worked as input.
Feedback	Respond to questions about the results.

Post-Instruction

Remediation	Additional homework exercises.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. II

Enabling Objective No. 10

Pre-Instruction

Motivation	Visualization..
Objective	Extend the use of the "visualization" technique on student generated examples.

Instruction

Presentation	Building on the wage example, students will generate other function models.
Examples	Student provided.
Embedded Tests	Accuracy of student generated models.

Activity

Practice	Section 3.3 in text.
Feedback	Respond to comments.

Post-Instruction

Remediation	Continued discussion.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. III

Enabling Objective No. 11

Pre-Instruction

Motivation	Computer animation.
Objective	Identify the effects of f(x) on an equation.

Instruction

Presentation	Demonstration of f(x) and y as interchangable notation.
Examples	Read the notation f(x). Interchange the notation.
Embedded Tests	Successful completion of examples.

Activity

Practice	Write equations with both notations.
Feedback	Task accomplishment.

Post-Instruction

Remediation	Continued practice with functions.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. III

Enabling Objective No. 12

Pre-Instruction

Motivation	Computer animation.
Objective	Discuss the appropriateness of using f(x) or y notation.

Instruction

Presentation	Use of notation as a means to enhance understanding of the mathematical context.
Examples	From Section 3.3 in text.
Embedded Tests	Which notation is appropriate for various problems?

Activity

Practice	On-task participation.
Feedback	Student awareness of appropriate notation.

Post-Instruction

Remediation	Outside classroom use of notation.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. IV

Enabling Objective No. 13

Pre-Instruction

Motivation	Computer animation.
Objective	Write the steps in the evaluation of a function using color coding for the input value.

Instruction

Presentation	Computerized replacement of x with specified values.
Examples	$f(x) = 3x + 2$ at 0, at 1, and at 2. $f(x) = 3x^2 - 4x + 5$ at 1 and at -2.
Embedded Tests	$f(1)$ when $f(x) = 5x - 1$. $f(-1)$ when $f(x) = 5x - 1$.

Activity

Practice	During an "exam," the student will evaluate a function at a specified value.
Feedback	Instructor evaluation.

Post-Instruction

Remediation	Continued practice.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. IV

Enabling Objective No. 14

Pre-Instruction

Motivation	Kinesthetic and visual reinforcement.
Objective	Write a mathematical procedure for evaluating functions paralleled in "words" and "symbols."

Instruction

Presentation	Mathematical problem solving steps paralleled with words.
Examples	Instructor provided.
Embedded Tests	Inspection of student work at desks.

Activity

Practice	Student homework exercises.
Feedback	Check on written entries.

Post-Instruction

Remediation	Additional examples.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. IV

Enabling Objective No. 15

Pre-Instruction

Motivation	Computer animation.
Objective	Form ordered pair relationships described by f(x).

Instruction

Presentation	Computer demonstration of ordered pair formation.
Examples	Form ordered pairs for $f(x) = 3x + 2$ at 0, at 1, and at 2. Form ordered pairs for $f(x) = 3x^2 - 4x + 5$ at 1 and at -2.
Embedded Tests	Form an ordered pair after finding f(1) when $f(x) = 5x - 1$. Form an ordered pair after finding f(-1) when $f(x) = 5x - 1$.

Activity

Practice	Section 3.3 in text.
Feedback	Back of the book answers for immediate feedback.

Post-Instruction

Remediation	Additional exercises.
Enrichment	Assist students in developing alternative exercise problems to challenge.

INSTRUCTIONAL STRATEGY

Topic No. V

Enabling Objective No. 16

Pre-Instruction

Motivation	Salary example.
Objective	Identify the relationship between weekly wages and hourly wage.

Instruction

Presentation	Group discussion of student findings.
Examples	Student provided.
Embedded Tests	Participation in the discussion.

Activity

Practice	Classroom participation.
Feedback	Instructor directed.

Post-Instruction

Remediation	Continued discussion.
Enrichment	Additional reading.

INSTRUCTIONAL STRATEGY

Topic No. V

Enabling Objective No. 17

Pre-Instruction

Motivation	Increased awareness of this calculus readiness topic as it relates to the real world.
Objective	State examples of linear and cubic functions in the real world.

Instruction

Presentation	Scientific presentation of real life data.
Examples	Running the mile. Aids.
Embedded Tests	None. This is motivational and not a required performance objective.

Activity

Practice	None.
Feedback	None.

Post-Instruction

Remediation	None.
Enrichment	Additional examples.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 18

Pre-Instruction

Motivation	What shapes occur in the real world? What path does a baseball follow? How does a satellite dish work?
Objective	Discuss patterns of algebraic equations.

Instruction

Presentation	Examples of linear, quadratic, cubic, logarithmic, absolute value, exponential, rational, and radical equations will be discussed.
Examples	$y = x$, $y = x^2$, $y = x^3$, $y = \log x$, $y = \|x\|$, $y = b^x$, $y = f(1,x)$, $y = r(x)$.
Embedded Tests	Student identification of patterns.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 19

Pre-Instruction

Motivation	Where does a linear equation occur in the real world?
Objective	Identify the "shape" of a linear function.

Instruction

Presentation	Mathematical and real world examples of linear equations.
Examples	Instructor provided in the form of $ax + by = c$.
Embedded Tests	Student identification of patterns.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 20

Pre-Instruction

Motivation	Where does a quadratic equation occur in the real world?
Objective	Identify the "shape" of a quadratic function.

Instruction

Presentation	Mathematical and real world examples of quadratic equations.
Examples	Instructor provided in the form of $y = a(x - h)^2 + k$.
Embedded Tests	Student recognition of quadratics through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 21

Pre-Instruction

Motivation	Where does a cubic equation occur in the real world?
Objective	Identify the "shape" of a cubic function.

Instruction

Presentation	Mathematical and real world examples of cubic equations.
Examples	Instructor provided in the form of $y = x^3$.
Embedded Tests	Student recognition of cubics through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY

Topic No. VI

Enabling Objective No. 22

Pre-Instruction

Motivation	Where does a logarithmic equation occur in the real world?
Objective	Identify the "shape" of a logarithmic function.

Instruction

Presentation	Mathematical and real world examples of logarithmic equations.
Examples	Instructor provided in the form of y = log x.
Embedded Tests	Student recognition of logarithms through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 23

Pre-Instruction

Motivation	Where does an absolute value equation occur in the real world?
Objective	Identify the "shape" of an absolute value equation.

Instruction

Presentation	Mathematical and real world examples of an absolute value equation.
Examples	Instructor provided in the form of $y = \|x\|$.
Embedded Tests	Student recognition of absolute value equations through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 24

Pre-Instruction

Motivation	Where does an exponential equation occur in the real world?
Objective	Identify the "shape" of an exponential function.

Instruction

Presentation	Mathematical and real world examples of exponential equations.
Examples	Instructor provided in the form of $y = b^x$.
Embedded Tests	Student recognition of exponential equations through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VI

Enabling Objective No. 25

Pre-Instruction

Motivation	Where does a rational equation occur in the real world?
Objective	Identify the "shape" of a rational function.

Instruction

Presentation	Mathematical and real world examples of rational equations.
Examples	Instructor provided in the form of $y = \frac{1}{x}$.
Embedded Tests	Student recognition of rational equations through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY

Topic No. VI

Enabling Objective No. 26

Pre-Instruction

Motivation	Where does a square root equation occur in the real world?
Objective	Identify the "shape" of a square root function.

Instruction

Presentation	Mathematical and real world examples of square root equations.
Examples	Instructor provided in the form of $y = \sqrt{x}$.
Embedded Tests	Student recognition of square root equations through discussion response.

Activity

Practice	Student identification of patterns.
Feedback	Discuss identification.

Post-Instruction

Remediation	Assist students with identification of patterns.
Enrichment	Find additional real world examples of mathematical equations.

INSTRUCTIONAL STRATEGY Topic No. VII

Enabling Objective No. 27

Pre-Instruction

Motivation	How do you recognize a function geometrically?
Objective	Identify a function when given the graph.

Instruction

Presentation	Question and answer session on the meaning of a function.
Examples	Instructor provided.
Embedded Tests	Find the functions from given graphs.

Activity

Practice	Examples from Section 3.3 of text.
Feedback	Discuss reasons for particular selections.

Post-Instruction

Remediation	Section 3.3 from text.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. VII

Enabling Objective No. 28

Pre-Instruction

Motivation	How do you recognize a relation geometrically?
Objective	Identify a relation when given the graph.

Instruction

Presentation	Question and answer session on the meaning of a relation.
Examples	Instructor provided.
Embedded Tests	Find the relations from given graphs.

Activity

Practice	Examples from Section 3.3 of text.
Feedback	Discuss reasons for particular selections.

Post-Instruction

Remediation	Section 3.3 from text.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. VIII

Enabling Objective No. 29

Pre-Instruction

Motivation	Anthropometry.
Objective	Use anthropometry to study a real world linear equation.

Instruction

Presentation	Discussion of anthropometry.
Examples	Wrist circumference and neck circumference is linear!
Embedded Tests	Participation in the classroom exercise.

Activity

Practice	Classroom data collection.
Feedback	Graph the data.

Post-Instruction

Remediation	None.
Enrichment	Additional reading on anthropometry.

INSTRUCTIONAL STRATEGY Topic No. VIII

Enabling Objective No. 30

Pre-Instruction

Motivation	Real world example of split-plot.
Objective	Graph linear equations with split-plot.

Instruction

Presentation	Graph $y = 5x$. Graph $y = 3.5x$.
Examples	$f(x) = 5x$ if $x < 100$ $3.5x$ if $x \geq 100$.
Embedded Tests	Instructor observation of student work.

Activity

Practice	Section 6.1 from text.
Feedback	Check answers in back of book.

Post-Instruction

Remediation	Additional examples.
Enrichment	Use of graphing calculator to do split-plot.

INSTRUCTIONAL STRATEGY Topic No. IX

Enabling Objective No. 31

Pre-Instruction

Motivation	Computer animation.
Objective	Compare the input of the function machine to the domain.

Instruction

Presentation	A function machine will be used to visualize the concept of domain.
Examples	Instructor provided.
Embedded Tests	Participation in classroom discussion.

Activity

Practice	Section 3.3 in text.
Feedback	Assist students on an individual basis.

Post-Instruction

Remediation	None.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. IX

Enabling Objective No. 32

Pre-Instruction

Motivation	Visualization.
Objective	Use the graph on a Cartesian plane to identify the domain.

Instruction

Presentation	Comparison of the domain of point graphs, rays, line segments, and lines.
Examples	Computer generated.
Embedded Tests	Describe the domain of selected examples.

Activity

Practice	Student will identify the domain in textbook exercises from Section 3.3.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. XI

Enabling Objective No. 33

Pre-Instruction

Motivation	Algebraic relationship to previous geometric approach.
Objective	Write the domain from the algebraic equation.

Instruction

Presentation	Identification of restricted domain.
Examples	$y = \frac{2}{x}$. $y = \sqrt{x}$.
Embedded Tests	Find the domain of the given examples.

Activity

Practice	Student will attempt to use suggested strategies during homework assignment in Section 6.1 and 7.2.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice of the strategies.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. IX

Enabling Objective No. 34

Pre-Instruction

Motivation	Algebraic relationship to previous geometric approach.
Objective	List the general restrictions on the domain of a function.

Instruction

Presentation	Division by zero is restricted.Negative radicands are restricted.
Examples	$y = \frac{2}{x}$. $y = \sqrt{x}$.
Embedded Tests	Student generated examples of restricted domain.

Activity

Practice	Student will attempt to use suggested strategies during homework assignment in Section 6.1 and 7.2.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice of the strategies.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. X

Enabling Objective No. 35

Pre-Instruction

Motivation	Computer animation.
Objective	Compare the output of the function machine to the range.

Instruction

Presentation	A function machine will be used to visualize the concept of range.
Examples	Instructor provided.
Embedded Tests	Participation in classroom discussion.

Activity

Practice	Section 3.3 in text.
Feedback	Assist students on an individual basis.

Post-Instruction

Remediation	None.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. X

Enabling Objective No. 36

Pre-Instruction

Motivation	Visualization.
Objective	Use the graph on a Cartesian plane to identify the range.

Instruction

Presentation	Comparison of the range of point graphs, rays, line segments, and lines.
Examples	Computer generated.
Embedded Tests	Describe the range of selected examples.

Activity

Practice	Student will identify the range in textbook exercises from Section 3.3.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. X

Enabling Objective No. 37

Pre-Instruction

Motivation	Algebraic relationship to previous geometric approach.
Objective	Write the range from the algebraic equation.

Instruction

Presentation	Identification of restricted range.
Examples	$y = \frac{2}{x}$. $y = \sqrt{x}$.
Embedded Tests	Find the range of the given examples.

Activity

Practice	Student will attempt to use suggested strategies during homework assignment in Section 6.1 and 7.2.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice of the strategies.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. X

Enabling Objective No. 38

Pre-Instruction

Motivation	Algebraic relationship to previous geometric approach.
Objective	List the general restrictions on the range of a function.

Instruction

Presentation	The change in range due to the division by zero restriction on the domain. The change in range due to the negative radicand restriction on the domain.
Examples	$y = \frac{2}{x}$. $y = \sqrt{x}$. $y = \|x\|$.
Embedded Tests	Student generated examples of restricted domain and the resulting changes in range.

Activity

Practice	Student will attempt to use suggested strategies during homework assignment in Section 6.1 and 7.2.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice of the strategies.
Enrichment	None.

INSTRUCTIONAL STRATEGY

Topic No. XI

Enabling Objective No. 39

Pre-Instruction

Motivation	Familiarity with arithmetic operations of +, -, ·, ÷ .
Objective	Discuss the four operations: addition, subtraction, multiplication, and division as they relate to functions.

Instruction

Presentation	Students will discover basic notation for the algebra of functions.
Examples	Student generated.
Embedded Tests	Discussion of student generated examples.

Activity

Practice	Examples from Section 5.5 in text.
Feedback	Self-evaluation.

Post-Instruction

Remediation	None.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. XI

Enabling Objective No. 40

Pre-Instruction

Motivation	Shortcuts.
Objective	Use the function notation for addition, subtraction, multiplication, and division of functions.

Instruction

Presentation	Introduce the notation and the alternative forms.
Examples	$(f+g)(x) = f(x) + g(x)$. $(f-g)(x) = f(x) - g(x)$. $(fg)(x) = f(x) \cdot g(x)$. $(\frac{f}{g}(x)) - \frac{f(x)}{g(x)}$.
Embedded Tests	Instructor observation of student work.

Activity

Practice	Homework in Section 5.5 in text.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Additional practice from Section 5.5 homework.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. XI

Enabling Objective No. 41

Pre-Instruction

Motivation	Computer animation.
Objective	Algebraically find the sum, difference, product, and quotient of functions.

Instruction

Presentation	Use the following rules to simplify algebraic problems: $(f + g)(x) = f(x) + g(x)$. $(f - g)(x) = f(x) - g(x)$. $(fg)(x) = f(x) \cdot g(x)$. $(\frac{f}{g}(x)) - \frac{f(x)}{g(x)}$.
Examples	Instructor provided.
Embedded Tests	Question and answers.

Activity

Practice	Homework from Section 5.5 in text.
Feedback	Self-evaluation.

Post-Instruction

Remediation	Continued practice of the strategies from Section 5.5 in text.
Enrichment	None.

INSTRUCTIONAL STRATEGY Topic No. XI

Enabling Objective No. 42

Pre-Instruction

Motivation	Computer animation.
Objective	Geometrically demonstrate the addition, subtraction, multiplication, and division of functions.

Instruction

Presentation	Computer animation of the algebra of functions.Graphing calculator reinforcement of the algebra of functions.
Examples	Instructor provided.
Embedded Tests	Graphing calculator reinforcement of concepts.

Activity

Practice	Homework from Section 5.5.
Feedback	Graphing calculator reinforcement.

Post-Instruction

Remediation	Graphing calculator practice.
Enrichment	Additional information from the test taking study skill seminars.

APPENDIX C

STRATEGY SEQUENCING

STRATEGY SEQUENCING

This unit is designed for use across 5 lessons of 75 minutes each.

Objective number	Time Required	Lessons
Overview/pretest	30 minutes	
I.1	5 minutes	
I.2	10 minutes	
I.3	10 minutes	
I.4	5 minutes	
I.5	10 minutes	
I.6	5 minutes	
I.7	5 minutes	
II.1	5 minutes	
II.2	5 minutes	
II.3	5 minutes	
III.1	10 minutes	
III.2	5 minutes	1 day
IV.1	15 minutes	
IV.2	15 minutes	
IV.3	5 minutes	
V.1	5 minutes	
V.2	5 minutes	
VI.1	10 minutes	
VI.2	5 minutes	
VI.3	5 minutes	
VI.4	5 minutes	
VI.5	5 minutes	

VI.6	5 minutes	
VI.7	5 minutes	
VI.8	5 minutes	
VI.9	5 minutes	
VII.1	5 minutes	
VII.2	5 minutes	1 day
VIII.1	5 minutes	
VIII.2	15 minutes	
IX.1	5 minutes	
IX.2	15 minutes	
IX.3	5 minutes	
IX.4	5 minutes	
X.1	5 minutes	
X.2	10 minutes	
X.3	5 minutes	
X.4	5 minutes	
XI.1	5 minutes	
XI.2	5 minutes	
XI.3	15 minutes	
XI.4	15 minutes	1 day
Summary/Posttest	30 minutes	1 day

REFERENCES

Alesandrini, K. L. (1982). CAI should differ from tradition. Electronic Education, 2(2), 15, 22-23.

Alesandrini, K. L. (1987). Computer graphics in learning and instruction. In D. Willows and H. Houghton (Eds.), The psychology of illustration (pp. 159-188). New York: Springer-Verlag.

Baird, W. E. (1986-1987, Winter). The influence of computers and informatics on mathematics and its teaching. The Journal of Computers in Mathematics and Science Teaching, pp. 49-51.

Bajgier, S. M., Atkinson, M., & Prybutok, V. R. (1989). Visual fits in the teaching of regression concepts. The American Statistician, 43(4), 229-234.

Balla, J. (1987). Microcomputers and teaching school mathematics: An answer to the challenge. Australian Mathematics Teacher, 43(1), 2-4.

Bell, A., & Janvier, C. (1981). The interpretation of graphs representing situations. For the Learning of Mathematics: An International Journal of Mathematics Education, 2(1), 34-42.

Bitter, G. G., & Camuse, R. A. (1988). Using a microcomputer in the classroom (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Black, K. J. (1988, May/June). Computer-augmented teaching: The computer screen versus the chalkboard. Academic Computing, pp. 46-49.

Bland, J. M. (1984). Using a microcomputer as a visual aid in the teaching of statistics. The Statistician, 33, 253-259.

Borg, W. R., & Gall, M. D. (1989). Educational research (5th ed.). New York: Longman.

Butzin, S. M. (1992, December). Integrating technology into the classroom: Lessons from the project CHILD experience. Phi Delta Kappan, pp. 330-333.

Byers, C. R. (1974). A comparison of computer-supported instructional techniques in statistics. In G. W. Dickson (Ed.), Monograph on innovative education (pp. 57-89). Atlanta, GA: The American Institute for Decision Sciences.

Capron, H. L. (1992). Essentials of computing. Redwood City, CA: Benjamin/Cummings.

Chipman, S. F., & Segal, J. W. (1985). Higher cognitive goals for education: An introduction. In S. F. Chipman & J. W. Segal (Eds.), Thinking and learning skills (pp. 1-19). Hillsdale, NJ: Erlbaum.

Clariana, R. B., & Schultz, C. W. (1993). Gender by content achievement differences in computer-based instruction. Journal of Computers in Mathematics and Science Teaching, 12(3/4), 277-288.

Clement, J. (1989). The concept of variation and misconceptions in Cartesian graphing. Focus on Learning Problems in Mathematics, 11(1-2), 77-87.

College Entrance Examination Board. (1989a). Descriptive test of mathematical skills for functions and graphs. New York: Author.

College Entrance Examination Board. (1989b). Descriptive tests of mathematical skills for functions and graphs: Instructor's guide. New York: Author.

College Entrance Examination Board. (1989c). Guide to the use of descriptive tests of mathematical skills. New York: Author.

Creswell, J. W. (1994). Research design. Thousand Oaks, CA: Sage.

Dallal, G. E. (1988). Statistical microcomputing--like it is. The American Statistician, 42(3), 212-216.

Darken, B. (1995). American mathematical association of two year colleges: Standards for developmental and introductory college mathematics. In J. L. Higbee & P. L. Dwinell (Eds.), Selected conference papers (pp.9-10). Chicago: National Association of Developmental Education.

DeMarois, P., McGowen, M., & Whitkanack, D. (1996). Mathematical investigations: An introduction to algebraic thinking. New York: Harper Collins.

Dick, W., & Carey, L. (1978). The systematic design of instruction. Glenview, IL: Scott, Foresman and Company.

Doerr, C. (1979). Microcomputers and the 3 r's: A guide for teachers. Rochelle Park, NJ: Hayden Book.

Dubinsky, E., & Harel, G. (Eds.). (1992). The concept of function: Aspects of epistemology and pedagogy. Washington, DC: Mathematical Association of America (MAA).

Dugdale, S. (1982). Green globs: A microcomputer application for graphing of equations. Mathematics Teacher, 75, 208-214.

Dugdale, S., Thompson, P. W., Harvey, W., Demana, F., Waits, B. K., Kiernan, C., McConnell, J. W., & Christmas, P. (1995). Technology and algebra curriculum reform: Current issues, potential directions, and research questions. Journal of Computers in Mathematics and Science Teaching, 14(3), 325-357.

Dunbar, S. B. (1992). Descriptive tests of mathematics skills. In J. J. Kramer and J. C. Conoley (Eds.), The eleventh mental measurements yearbook (pp. 277-278). Lincoln, NE: University of Nebraska Press.

Durant, K., & Garofalo, J. (1994). Teaching functions and graphing in pre-calculus mathematics. The Journal of Developmental Education, 18(1), 18-24.

Edwards, S. E. (1982). Use of microcomputers at the junior college level in teaching of mathematics. Unpublished master's thesis, San Jose State University, San Jose, CA.

Gagne, R. M., Briggs, L. J., & Wager, W. W. (1992). Principles of instructional design (4th ed.). Orlando, FL: Harcourt Brace Jovanovich.

Galbreath, J. (1992, April). The educational buzzword of the 1990's: Multimedia, or is it hypermedia, or interactive multimedia, or ...? Educational Technology, pp. 15-19.

Ganguli, A. B. (1992). The effect on students' attitudes of the computer as a teaching aid. Educational Studies in Mathematics, 23(6), 611-618.

Garofalo, J., & Durant, K. (1991). Applied functions and graphs: A necessary topic for developmental mathematics. Research & Teaching in Developmental Education, 8(1), 51-55.

Gilder, G. (1993, March). The Information revolution. The Executive Educator, pp. 16-20.

Gilligan, W. P. (1991). The use of a computer statistical package in teaching a unit of descriptive statistics (Doctoral dissertation, Boston University, 1990). Dissertation Abstracts International, 51, 2302A.

Goldenberg, E. P. (1988). Mathematics, metaphors, and human factors: Mathematical, technical, and pedagogical challenges in the educational use of graphical representation of functions. Journal of Mathematical Behavior, 7, 135-173.

Goldsmith, E. (1984). Research into illustration. Great Britain: Cambridge University Press.

Gordon, F. S., & Gordon, S. P. (1989). Computer graphics simulations of sampling distributions. Collegiate Microcomputer, 7(2), 185-189.

Govea, R. M. (1989). Some observations on computer education for political science students. Teaching Political Science: Politics in Perspective, 16(4), 153-156.

Gray, C. (1973). Expressed student attitude toward conventional versus computer supplemented instruction. Decision Sciences, 4, 141-148.

Greenfield, E. (1993, May). Evolution of the textbook: From print to multimedia. Technological Horizons in Education, pp. 12-19.

Hester, J. R. (1992). Descriptive tests of mathematics skills. In J. J. Kramer and J. C. Conoley (Eds.), The eleventh mental measurements yearbook (pp. 278-279). Lincoln, NE: University of Nebraska Press.

Hinkle, D. E., Wiersma, W., & Jurs, S. G. (1988). Applied statistics for the behavioral sciences (2nd ed). Boston: Houghton Mifflin.

Hollowell, K. A., & Duch, B. J. (1991). Functions and statistics with computers at the college level. Paper presented at the meeting of the Annual Conference of the American Educational Research Association, Chicago, IL.

Houston, D. M. (1993). An exploration and analysis of the relationship among learning styles, teaching styles, gender and performance in a college computer science course (Doctoral dissertation, Kansas State University, 1994). Dissertation Abstracts International, 54, 2997A.

Howles, L., & Pettengill, C. (1993, June). Designing instructional multimedia presentations: A seven-step process. Technological Horizons in Education, pp. 58-61.

Imboden, H. H. (1985). The effects of computer enhanced instruction in teaching concepts of percent to low achieving college students (Doctoral dissertation, University of Missouri, 1985). Dissertation Abstracts International, 46, 10A.

Ingram, J. K. (1987). Implementing and assessing computer-augmented-teaching in the large lecture course (Doctoral dissertation, Northwestern University, 1987). Dissertation Abstracts International, 48, 11A.

Johnson, C. D. (1994). Computer-assisted, computer-based, and traditional instruction: Effects on developmental students' vocabulary knowledge. Research in Developmental Education, 11(4).

Johnson, L., & Perez, S. (1996, May). Meeting the challenge: Final report of the computer-based developmental education project. Mission Viejo, CA: League for Innovation in the Community College.

Karplus, R. K. (1979). Continuous functions: Students' viewpoints. European journal of science education, 1(4), 397-413.

Kemeny, J. G. (1991). Software for the classroom. Mathematics and Computer Education, 25(1), 33-37.

Kerslake, D. (1977). The understanding of graphs. Mathematics in School, 6(2), 56-63.

Khalili, A. & Shashaani, L. (1994). The effectiveness of computer applications: A meta-analysis. Journal of Research on Computing in Education, 27(1), 48-61.

Kiser, L. (1990). Interaction of spatial visualization with computer-enhanced and traditional presentations of linear absolute-value inequalities. The Journal of Computers in Mathematics and Science Teaching, 10(1), 85-96.

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

Kulik, J. A., Kulik, C. C., & Cohen, P. A. (1980). Effectiveness of computer-based college teaching: A meta-analysis of findings. Review of Educational Literature, 50(4), 525-544.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. Review of Educational Research, 60(1), 1-64.

Lillie, D. L., Hannum, W. H., & Stuck, G. B. (1989). Computer and effective instruction. New York: Longman.

Lovell, K. (1970, October). Some aspects of the growth of the concept of a function. In M. F. Rosskipf, L. P. Steffe, & S. Taback (Eds.), Piagetian Cognitive-Development Research and Mathematical Education (pp.12-33). Reston, VA: National Council of Teachers of Mathematics.

Lumsden, D. B. (1974). Individualizing instruction through the use of programmed instruction. The Educational Forum, 38(2),145-152.

Malik, M. A. (1980). Historical and pedagogical aspects of the definition of function. International Journal of Mathematics Education and Science Technology, 11(4), 489-492.

Markovits, Z., Eylon, B., & Bruckheimer, M. (1986). Functions today and yesterday. For the Learning of Mathematics, 6(2), 18-28.

Mayes, R. L (1995). The application of a computer algebra system as a tool in college algebra. School Science and Mathematics, 95(2), 61-68.

McGrath, D. (1994). An exploration and analysis of the relationship among learning styles, teaching styles, gender, and performance in a college computer science course (Doctoral dissertation, Kansas State University, 1993). Dissertation Abstracts International, 54, 8A.

McKeague, C. H. (1996). Functions & graphs Orlando, FL: Harcourt Brace.

National Council of Teachers of Mathematics (NCTM). (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM.

Neter, J., & Chervany, N. (1973). Effects of use of computer in first-year statistics sequence on student attitudes. Decision Sciences, 4, 133-139.

Nygard, K. E., & Ranganathan, B. (1983). A system for generating instructional computer graphics. AEDS Journal, 16, 177-187.

Pascarella, E. T., & Terenzini, P. T. (1991). How college affects students. San Francisco: Jossey-Bass.

Prybutok, V. R., Bajgier, S. M., & Atkinson, M. (1991). Statistics instruction: The next generation. The Journal of Computers in Mathematics and Science Teaching, 10(3), 15-27.

Sawyer, W. D (1992, January). The virtual computer: A new paradigm for educational computing. Educational Technology, pp. 7-14.

Schneider, K. C. (1977). Computer supported instruction in statistics: Long range implications. Decision Sciences, 8, 318-331.

Silberman, H. F. (1969). Applications of computers in education. In R. Atkinson & H. Wilson (Eds.), Computer-assisted instruction (pp. 49-61). New York: Academic Press.

Smith, D. A. (1982, Summer). Using computer graphics to teach mathematics. The Journal of Computers in Mathematics and Science Teaching, pp. 24-27.

Spatz, C., & Johnston, J. O. (1976). Basic statistics: Tales of distributions. Monteray, CA: Brooks/Cole.

Steinberg, E. R., Baskin, A. B., & Hofer, E. (1986). Organizational/memory tools: A technique for improving problem solving skills. Journal of Educational Computing Research, 2, 169-187.

Stockburger, D. W. (1982). Evaluation of three simulation exercises in an introductory statistics course. Contemporary Educational Psychology, 7, 365-370.

Super, J. (1993, January/February). Return on investment: Softening technology's up-front cost. Adult Learning, pp. 12-14.

Sutherland, R. (1993). Consciousness of the unknown. For the Learning of Mathematics, 13(1), 43-46.

Teles, E. J. (1991). Using the microcomputer to help students learn to interpret functional information. Mathematics and Computer Education, 25(3), 230-241.

Webster, E. (1992). Evaluation of computer software for teaching statistics. The Journal of Computers in Mathematics and Science Teaching, 11, 377-391.

Wiley, L. G. (1993). Relationships between teachers' attitudes, knowledge, and concerns about computers in education and a concerns-based approach to staff development. Dissertation Abstracts International, 54, 151A.

Willows, D. M., & Houghton, H. A. (1987). The psychology of illustration (Vol. 1). New York: Springer-Verlag.

Wilson, B. J. (1994). Technology and higher education: In search of progress in human learning. Educational Record, 75(3), 9-16.

Winn, B. (1987). Charts, graphs, and diagrams in educational materials. In D. Willows & H. Houghton (Eds.), The psychology of illustration (pp. 168-198). New York: Springer-Verlag.

Zimmermann, W., & Cunningham, S. (Eds.). (1991). Visualization in teaching and learning mathematics. Washington, DC: Mathematical Association of America (MAA).