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Groom, Retha Earline

**USING COMPUTER GRAPHICS AS A TOOL TO TEACH BEGINNING
ENGINEERING DESIGN GRAPHICS**

Texas A&M University

PH.D. 1982

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USING COMPUTER GRAPHICS AS A TOOL TO TEACH
BEGINNING ENGINEERING DESIGN GRAPHICS

A Dissertation

by

RETHA EARLINE GROOM

Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY

December 1982

Major Subject: Industrial Education

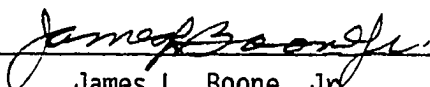
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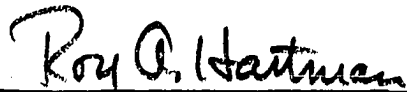
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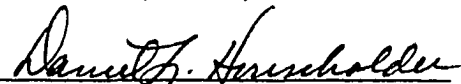
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December 1982

ABSTRACT

Using Computer Graphics as a Tool to Teach Beginning
Engineering Design Graphics. (December 1982)

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M.S., Memphis State University

Chairman of Advisory Committee: Dr. G. Dale Gutcher

The purpose of this study was to determine if the use of a combination of traditional manual drawing and user-oriented interactive computer graphics was an efficient method to teach engineering graphics and serve as an introduction to computer graphics for first semester engineering graphics students.

Five topics of instruction selected to implement this research were bargraph, breakeven graph, orthographic projection, isometrics, and obliques. On each separate topic, an entire engineering graphics class was given the same lecture and then drew the first assignment on that topic using traditional manual drawing methods. For a subsequent drawing on each topic, a control group made the drawing through manual methods. Concurrently, a treatment group made a similar drawing using computer graphics that required no programming.

The treatment was evaluated by analysis of variance on three major measurements. On five separate weekly quizzes, there was no practical difference between the groups. The pre-post test scores on the

departmental comprehensive examination showed a significant interaction in favor of the treatment group. Although the primary purpose of this study was not to teach computer graphics but rather to use computer graphics as a teaching tool, students were tested to determine if they meanwhile had increased their knowledge and improved their attitude toward using computer graphics. As expected, the treatment group did learn additional information and did improve their attitude toward using computer graphics while performing as well as the manual group on short-term weekly quizzes and better on the long term examination. The computer graphics group accomplished this while requiring far less time (5 minutes versus 42 minutes) to solve the same engineering graphics problems.

Based on this research, it is recommended that this method of teaching first-semester freshman engineering graphics principles through a combination of manual drawing followed by interactive computer graphics be implemented as soon as possible into first-semester engineering graphic courses in colleges and universities which have interactive computer graphic facilities. Additional areas of course content could also be included with the program because of time saved in solving supplementary problems.

ACKNOWLEDGMENTS

My appreciation is extended to the committee members of the Industrial Education Department for their assistance throughout this educational endeavor. Dr. G. Dale Gutcher, Dr. James L. Boone, Jr., and Dr. Donald L. Clark all contributed to the success of this project. Also, Dr. G. E. Baker's assistance was appreciated while he was committee chairman prior to his temporary summer absence.

During the progress of this project, several people in the Engineering Design Graphics Department at Texas A&M University deserve special thanks for their support and cooperation: Dr. James H. Earle, head of the department, for allowing the use of students and facilities of the department; Dr. Roy A. Hartman for his general support and assistance during the project; Dr. Robert A. Wilke for his general cooperation and assistance with the software for the project; William H. Zaggle for his assistance with the hardware.

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CHAPTER I

INTRODUCTION

Change and expansion are some of the basic facts of life in an advancing society. These can include everything from advancing technologies to inflation and social changes. Among those caught in this age of expansion are educators who are charged with preparing their students to make use of the new technologies as well as continuing to use the appropriate traditional methods (Toffler, 1970). An area in technology that is advancing faster than any other is the field of computer electronics (Reed, 1980). Today, there are approximately ten million computers in existence and "if the trend continues, sometime in the 1990's the number of computers in the world will exceed the number of people" (Quantz, 1982, p. 23). Being able to use these computers is a national concern. Luehrmann said, "The ability to use computers is as basic and necessary to a person's formal education as reading, writing, and arithmetic" (1980, p. 98). Jordan's (1969) survey indicated that in the late 1960's, the second largest use of computers in industry was for engineering design and calculations; the largest industrial use of computers was for data processing. As Kearns points out, "the computer is a powerful

The citations on this and the following pages follow the style of the Journal of Industrial Teacher Education.

computational tool. Its use has led to radical changes in engineering methods and procedures. Indeed, it is now possible to obtain solutions to problems that would not have been attempted a few years ago" (1973, p. 2).

Another tool for engineers, but one that has been used for many centuries instead of a few years, is that of graphics. "Graphical representation closely parallels man's technological progress, from the earliest records of his existence up to the present day" (Land, 1976, p. 28).

Along with verbal and mathematical expression, graphical expression is a necessary tool for the exposition of engineering ideas. The engineer must be skilled in the use of all three media and in the translation of ideas from one medium to another. (Smith, 1969, p. 324)

Graphics has been called the language of design (Sell, 1977), of industry (Smith, 1969), and of engineering (Spotts, 1981). In the past, as now, it has had the very practical purpose of recording ideas and transmitting instructions (Smith, 1969). As a language, graphics can be used to communicate ideas to others and to communicate with oneself (Earle, 1977). In some engineering schools, graphics is taught in a separate department of engineering graphics, while at other schools, it is included as part of another department, such as mechanical engineering. As mentioned by Sell (1977), some of the basic drawings covered in engineering graphics are pictorial drawings (isometrics and obliques), orthographic projection, working drawings, graphs and charts.

One rapidly developing use of computers is computer graphics which "involves the computer-generated drawing of an actual physical

object or a schematic representation thereof" (Barr, 1982, p. 172). Some have even heralded it as the beginning of another industrial revolution. It is claimed that next to electricity, computer graphics has the greatest potential for increasing industrial productivity (Bylinsky, 1981). Although computer graphics began in the mid 1950's (Chasen, 1981; Quantz, 1982), the single most identifiable event that promoted computer graphics was the publication of Ivan Sutherland's dissertation at the Massachusetts Institute of Technology in 1962. This dissertation explained how "Sketchpad" was used to enable man to interface with the computer through the language of graphics; now, man could communicate with the computer through graphics in regard to what three dimensional figures looked like. By the mid 1960's, computer graphics was being used on large research projects in major industries such as General Motors and Lockheed Aircraft (DiCurcio, 1972).

The main industrial application of computer graphics is for engineering drawings; the primary reasons for its use are speed, overall cost savings, and accuracy (Case, 1971; Ryan, 1975). The obvious reason computer graphics was slow to become attractive was its start-up cost (Wozny, 1978), but by the 1970's the research initiated earlier in the larger industries had begun to filter down and to be helpful in the smaller industries and engineering firms (Demel, Kent, & Zaggle, 1979; Newman & Sproull, 1979). At present, computer graphics is being used in many types of industries including piping design, air traffic control, vehicle simulators, and cartography (Demel, Wilke, Coppinger, & Barr, 1979; Zsomer-Murray, 1981). For the future, "the

trend in industrial design is toward increased use of computer graphics" (Wozny, 1978, p. 16). It allows the design engineer to interact, evaluate, and alter designs directly. Also, the engineer can completely eliminate the experimental verification stage and send the design into production if the product is well understood (Wozny, 1978).

College graduates with degrees in engineering and specialization in computer aided design/computer aided manufacturing (CAD/CAM) are highly recruited for several reasons. First-time industrial users of computer graphics systems have often been disappointed with the results of their systems. Often the problem is a lack of qualified employees who can direct the use and development of the system. Because the computer graphics industry is "growing at a compound rate of more than 40 percent annually, finding qualified personnel to develop and operate new graphics systems is sometimes difficult" (Cucuzzella, 1981, p. 13). Quantz said that the success of industrial use of CAD/CAM systems is in "direct proportion to the number of college graduate technical people in the organization" (Quantz, 1982, p. 52). In order to meet the demands for computer graphic operators, some companies have used their most highly educated engineers while taking the risk that these engineers might be needed more in other phases of the company work. Other companies merely train their own computer operators (Coppinger, 1981). Edwards (1977) also observed that many companies are using on-the-job training with their employees. In addition, his study indicated that there was a trend for colleges and universities to share in this training responsibility. However, because it is just

now gaining momentum, there is no well established method to introduce and teach computer graphics in the schools (Ryan, 1981; Zsomer-Murray, 1981).

Educators recognize that computer graphics needs to be taught in order to upgrade the curricula, but they are not in agreement regarding the level at which it should be taught, or whether it should be required or optional. Some educators said it should be a required course (McDougal, 1979, 1981) while other educators were more specific by having stated that it should be in a required, beginning (freshman) engineering design graphics class (Bechtold, 1968; Coppinger, 1974; Demel, Kent, & Zaggie, 1979; Hall, 1972; Mosillo, 1973, 1974; Zsomer-Murray, 1977). Levens (1982) recommended that a class in computer graphics be inserted between the two basic drawing classes in engineering graphics. Jasper pinpointed the department where computer graphics should be offered, without saying to what extent it should be taught, when she related that "all the engineering disciplines want computer graphics included in existing graphics curricula" (1981, p. 6). Other educators have used computer graphics as a tool while doing research on other topics (Erdman & Frohrib, 1975; Halpern, 1970; O'Leary, 1972; Otis, 1971; Raczkowski, 1973; Roberts, 1973) or have included it as part of an upper level technical course they were teaching (Charles, Galambos, & Gould, 1982; Roberts, 1973). Still others have researched the software development of it for various educational purposes (Hang, 1975; Pidgeon, 1975; Rotenberg, 1977). When computer graphics was taught at the freshman level, some also attempted to teach computer programming in varying degrees as well (Bechtold, 1968, 1971;

Coppinger, 1974; DeLorm & Smith, 1975; Zsomer-Murray, 1977). Some individuals in institutions of higher learning indicated that it should be used as a tool without requiring programming from the student (Beattie & Mulvenna, 1974; Demel, Kent, & Zaggie, 1979). Other educators taught it as an upper level course in computer graphics which also included programming (Brown, 1972; Demel & Coppinger, 1978; Dowling, 1976; Edwards, 1977; Moche1, 1970; West, 1972).

In his 1981 study, McDougal surveyed 225 universities in the United States and Canada. The respondents were asked whether computer graphics was used as a solution tool or if it was art-related. Thirty-seven responded that it was used for solutions, 11 used it for both solutions and art, and 28 indicated it was not offered at their institutions. There were no responses from 149 institutions.

Statement of the Problem

Engineering educators, in general, and engineering graphics educators, in particular, agree that computer graphics needs to be taught to engineering students so that they may stay abreast of developing technologies. Presently, educators are using a wide variety of approaches to teach computer graphics. However, the best way to give all engineering students a general introduction to computer graphics has not yet been firmly established. A very appropriate and logical place for the beginning students to have this introduction is in an engineering graphics class where graphic principles can be taught

through a combination of traditional methods and computer graphics (Barr & Demel, 1980; Ryan, 1981).

Objective

The objective of this study was to determine if the use of a combination of manual drawing and computer graphics is an efficient way to teach freshmen engineering design graphics and to serve as an introduction to computer graphics for the beginning engineering student.

Null Hypotheses

The following null hypotheses were tested in the study:

1. There is no significant difference in achievement between students who use a combination of both manual and user-oriented computer graphic exercises and students who use only manual exercises for selected questions on departmental weekly quizzes.
2. There is no significant difference in achievement (gain or loss from pre-test to post-test scores) of the overall course material between students using the combination of manual and user-oriented computer graphics exercises and students using only manual exercises as measured by the standard departmental comprehensive test.
3. There is no significant difference in achievement of computer graphic principles by students using a combination of manual and user-oriented computer graphics exercises and by students using only manual exercises as measured by a special computer graphics achievement test given as a pre-test, post-test I, and post-test II.

Assumptions

The following assumptions were made in this study:

1. The computer exercises would be user-oriented and would not require any programming experience.
2. The computer terminals and equipment would be ready, available, and maintained in good repair and would not cause any unreasonable delays.
3. The computer lessons would not hinder the scholastic progress of the Engineering Design Graphics (EDG) 105 students.

Limitations

The following limitations were imposed upon this study:

1. If the computer equipment was not in working order, the topics intended to be assigned as computer exercises at that time would either be deleted from the study and manual plates used instead, or the computer exercises would be postponed to a convenient later time.
2. Because of a limited number of computer graphic terminals within the EDG department which are regularly used by the more advanced computer graphics classes of EDG 408 and 409, this study was limited to only one class of EDG 105 students.

CHAPTER II

REVIEW OF RELATED LITERATURE

Computer graphics has been used in a wide variety of engineering education settings. The emphasis in Chapter II will be on the introduction of computer graphics in freshmen engineering graphics courses. However, related topics will be considered to a lesser extent. For the purpose of this review, the discussion of computer graphics will be grouped into the following two divisions:

1. Computer graphics in freshmen courses.
2. Computer graphics in courses above the freshman level.

Computer Graphics in Freshmen Courses

The problem facing engineering educators regarding computer graphics was expressed very recently by Barr:

Computer Graphics and Computer-Aided Design (CAD) are emerging topics in engineering education. Engineering educators generally agree that both concepts should be introduced in the undergraduate curriculum, perhaps as early as the freshman year. However, there is no general agreement on which is the best standard approach to take. (1982, p. 172)

As noted by Barr, the problem of introducing computer graphics has been recognized, but how to solve the problem has not yet been determined. Barr also included the related topic of computer-aided design which may or may not be studied together with computer graphics.

Introduction of Computer Graphics in Engineering Graphics

Many engineering educators have mentioned that computer graphics should be introduced early in the engineering curricula. A required freshman course was often suggested as the appropriate place for this introduction (McDougal, 1979). The one course suggested by the largest number of authors was Engineering Graphics (Barr, 1980, 1982, Coppinger, 1974; Demel, Kent, & Zaggie, 1979; Hall, 1972). Another suggested course was a required general engineering course such as Introduction to Engineering (Juricic & Barr, 1982). From institution to institution, there was some variation in which departments taught engineering graphics and computer programming. At some schools both courses were taught in the same department while at other schools different departments taught each course.

Juricic and Barr (1982) mentioned four levels for teaching computer graphics. The lowest level was "an introductory familiarization" (p. 183). They continued by stating:

The first, lowest level of computer graphics instruction should be offered to all freshmen engineering students. It does not require any prerequisite, and it could be incorporated into an existing freshman course such as Introduction to Engineering, or Engineering Graphics. It could be effective with as few as two lecture and five lab hours of the semester. (1982, p. 183)

Barr (1982) also reflected somewhat similar ideas regarding the introduction of computer graphics but narrowed the choice to engineering graphics. Initially, he combined computer graphics and CAD, but later he separated them.

While engineering graphics and drafting courses are well-established in the engineering curricula, the discipline of computer graphics is merely ten years-old and is only now becoming part of the syllabus. Yet many will agree that the freshman graphics course is a natural starting part [sic] to introduce computer graphics and CAD to the engineering student. These topics can then be pursued in more specific detail later on in upper division courses. (p. 172)

Later Barr distinguished between the teaching approaches for computer graphics and CAD. The distinction concerned computer programming. He stated, "It is not necessary for the student to understand computer programming in order to receive full benefit from introductory modules on computer graphics" (1982, p. 173). He implied that programming should be employed when CAD was taught.

Juricic (1980) recognized three ways that computer graphics can be introduced in freshman courses. These three ways were within the restraints present at most colleges and universities. That is, most freshmen students have not had any computer programming. The first way he mentioned was to not use any computer programming with the introductory experience--the students would only use interactive application programs. The second method would teach computer programming and computer graphics as a single course. The third way was to teach computer programming early in the freshman year and teach computer graphics later in the freshman year. According to Juricic, the first way was used in schools where different departments administer computer graphics and computer programming. He said that "the most frequent alternative is to have computer graphics following a programming course . . . or to cover necessary programming while teaching computer graphics" (1980, p. 350). Although other authors

have also mentioned ways similar to these three to teach computer graphics, none have specifically stated which ways were most commonly used.

Ten years earlier, Hall (1972) had already recognized the potential of computer graphics in engineering graphics:

Interactive computer graphics and automated design techniques are being heralded by some as the panacea for all of the problems encountered by engineering graphics departments as they endeavor to teach more material, including computer graphics, in the time usually allotted for a two or three semester hour course in engineering graphics It is agreed that computer graphics holds some very promising potentials which may be utilized to enhance the study of engineering graphics principles if they are used effectively and at the appropriate time. (p. 19)

Several years ago, Coppinger (1974) also agreed that computer graphics should be introduced in engineering graphics when he stated "that the engineering student should have at least an introduction to computer graphics, and the best place for this introduction is in an engineering freshmen graphics course" (p. 7). Coppinger went on to explain how students in three separate engineering graphics classes at Texas A&M University were introduced to computer graphics using some computer programming to solve the assigned problems. The assignments started with programming to add two numbers and eventually included programming to use subroutines to draw bargraphs. In summary, he said "It may be concluded that an introduction to computer graphics can be included in existing engineering freshmen graphics courses with a minimum of disruption to the existing course curriculum" (p. 9).

Barr and Demel (1980) supported the use of computer graphics in engineering graphics by stating "we think that the largest single

demand for computer graphics in course work is in freshmen engineering graphics" (p. 828). Barr and Demel recognized that most freshmen engineering graphics students need a user-oriented system because they have had little or no experience with computers.

More recently at Texas A&M University, Hartman (1981) reported about a class using computer graphics in a second semester freshman engineering design graphics course. The students were enthusiastic about the computer in their design projects but if they were pressed for time, the students would resort to lettering or drawing by hand rather than studying the user's guide to determine the correct way to use the computer. He concluded by recommending that computer graphics should probably be introduced sooner to the students--that is, during the first semester of freshman engineering design graphics.

Computer Graphics as a Tool

Although many claims have been made for computers and computer graphics, Slaby (1976) warned that caution should be used before these new technologies were carelessly applied anywhere. He stated that "in the technical areas the computer sometimes is used, just because it is there, not because it makes sense to use it for a particular problem" (p. 35). Under those circumstances, the computer becomes a machine that controls man, instead of a tool to help man. He continued by saying "that we should use the computer only if it enhances our powers to do creative designing and graphical communication and drafting" (p. 35); in other words, the computer should be

considered a tool to accomplish an objective. He said that because of its interactive capabilities, computer graphics could be used as "a very powerful learning and teaching tool" (p. 38). He concluded his discussion about interactive computer graphics in this manner: "The creative minds of men and women cannot, and I predict will not, be replaced by the computer. The computer can only assist our minds to do more in less time and with less energy and better results" (p. 38).

Earle (1977) agreed with Slaby regarding the use of computers. He stressed "that true creative design cannot be performed by a computer. The computer is best suited for repetitive operations based on factual information . . . and is incapable of generating original concepts of its own" (p. 367). By performing the repetitive tasks for the engineer, the computer has given the engineer more time to be creative himself.

Using computer graphics and related topics as a tool has been stressed by several authors. Goetsch (1981) referred to the related area of computer-aided-design (CAD) when he said:

It is helpful to present CAD as just another advance in time-saving devices for drafting. First there was the T-square, then the drafting machine, and now CAD. All of these things are simply tools to be used to improve drafting practices and the time involved in performing them. (p. 25)

The same things could have been said regarding computer graphics and engineering graphics as were said regarding CAD and drafting.

Juricic (1980) also mentioned computer graphics as a tool. He said that "from an engineer's point of view computer graphics is more a tool or technique than a discipline" (p. 350).

Although DeJong (1981) advocated that computer graphics should only be taught to a few students in an advanced level course, he did emphasize that computer graphics "is a TOOL [sic] and cannot communicate anything that its operator doesn't know initially" (p. 37). He called computer graphics "the electronic equivalent of a drafting machine" (p. 37).

Hall (1972) considered computer graphics as a teaching tool in engineering graphics when he said that "through the proper use of computer graphics one may effectively teach more material in the same allotted time while reducing the actual number of graphics problems that the student would be required to solve on the board" (p. 19). Thus, computer graphics has been considered as a tool in two ways. It is used as a tool by the engineer and draftsman, and it is also a teaching tool of the engineering graphics educator.

Teach Manual Method First

As previously stated, many engineering educators recognized that computer graphics should be introduced into engineering graphics courses. However, many authors insisted that the older traditional methods should still have a place in the graphics classroom.

When Hall (1972) discussed the role of computer graphics in engineering graphics, he recognized that the computer could be helpful, but that the computer could not replace entirely what the

graphics student would learn by solving problems on a drawing board. As previously mentioned, Hall recognized that if computer graphics is used properly, the graphics student could solve more graphics problems than drawing them all manually. Hall implied that there should be a mixture of manual and computer exercises when teaching engineering graphics. Later he added that the study of engineering graphics fundamentals should emphasize the traditional tools of the drawing board and triangles. Hall reflected that the graphics student might be motivated to study graphics through the use of the computer, but "to really learn the fundamental theory of engineering graphics and design, he must actually work a number of the problems himself" (p. 20) rather than watch all the problems displayed on the computer graphics screen.

LaRue (1981) very clearly stated that the traditional manual methods cannot be entirely replaced by computer graphics.

The fallacy of computer graphics eliminating the need for manual, pencil pushing graphics is shown by talking to managers of computerized drafting systems. . . . These people want individuals with a very strong background in drafting to become users of their systems. The same philosophy [sic] applies in many instances to engineers who are going into computer aided design. They need a background in graphics to effectively use computer graphics. (p. 9)

LaRue continued on to say that "graphics programs of the future should include both manual and computer graphics" (p. 9).

In a letter to the editor of Drafting & Repro Digest, Guetzlaff (1981), a senior designer for John Deere Product Engineering Center, recommended that the drafter should learn the fundamentals of

drawing and graphics the hard way (through manual drawing) before depending entirely on the computer. The editor, Myers (1981) agreed:

Mr. Guetzlaff is absolutely correct when he states a drafter, whether using a CAD system or not, must know the fundamentals of drawing, should be able to create drawings by manual methods, and the drawing must show the true intent of the design. CAD systems will help a competent drafter do the job, but they won't do the job for him.
(p. 27)

A recent unauthored article discussed industrial applications of computer graphics. First, the original ideas were conceived by an individual. Second, they were translated into a rough sketch manually. Third, the design was drawn with the computer (Personnel "crunch" solved, 1980). Thus in industry also, the manual method was used before the computer was employed.

When students in an engineering technology class were introduced to automated drafting at Southern Massachusetts University, Gorczyca and Barylski (1974) reported that the students first drew an isometric view of the object manually, before they were gradually shown how to write a computer program step-by-step to see the drawing produced with the computer. The students then compared the accuracy and quality "between the manually executed and the machine produced drawings" (p. 45). Thus, in the learning environment, there was a recognized need to experience the fundamental operations manually before showing how the computer could be used to speed up the process; also, the student was enabled to feel confident that the computer drawing could be verified if needed.

Simplify the Processes

Although it is possible to learn about industrial applications of many new technologies, educators need to use care in selecting the most appropriate applications of technologies to bring into the classroom. As Hall (1972) stated in regard to computer graphics, the "tools suitable for design and manufacturing in industry are not always in the best suitable form for educational use. As a general rule, they need to be modified and usually simplified before they can be used in the classroom" (p. 20). Bechtold (1971) also stressed that the concept should be kept simple. When computer graphics was introduced to freshmen engineering students, he reported that "simple but basic concepts were given in sufficient depth to make a lasting impression" (p. 369).

Mosillo and Wolf (1976) indicated that they too, had found that the simplified approach was best when introducing computer graphics in an engineering drawing class. Although they used some computer programming, over the years they reported that they have reduced the programming involved and have consequently "reduced the amount of work in the course substantially without reducing student interest or learning" (p. 41). The course is much better received by the students now, with many students deciding to take it as an elective.

How Much Programming?

As mentioned previously by two engineering educators from the University of Texas, Juricic (1980) and Barr (1980), a definite

consideration for introducing computer graphics during the freshman year was to determine how much computer programming to teach. In most cases, the freshman student has not had previous computer programming. This leads to three alternatives: "Teaching computer graphics without any programming, teaching programming before computer graphics, or using computer graphics to help teach computer programming" (Barr, 1980, p. 352). As mentioned by Juricic (1980), one factor that influenced the decision is whether or not the department teaching computer graphics also regularly teaches computer programming. Various colleges and universities handle programming in different manners. Likewise, engineering graphics is taught in different settings.

No programming. As discussed in the previous section, several educators have recommended keeping the introduction to computer graphics as simple as possible--simplicity can be applied specifically to computer programming. Simplifying the use of computer programming while introducing computer graphics in an engineering graphics class means ultimately not using any programming at all. Some educators have mentioned that the introduction to computer graphics should use programs which were "user-oriented" or "user-friendly" (Demel, Kent, & Zaggle, 1979; Wilke & Demel, 1980). Juricic (1980) and Barr (1980) reported that faculty at the University of Texas at Austin introduced computer graphics without requiring any programming knowledge from the students.

Beil (1980) reported that faculty from his university visited three industrial users of computer graphics in Tennessee. They found

that most of the engineers who were using computer graphics had not written the programs that they were using.

Hartman (1981) reported some difficulty in an attempt to introduce computer graphics to freshmen graphics students through the students' design projects. He mentioned that both software and hardware problems were experienced and the students were somewhat reluctant to study the user's guide for the computer when they were pressed for time. The implication here is that the process needed to be simplified to enable the student to use the computer with greater ease. Although the programs were already user-oriented and did not require programming, the software needed to be less obtrusive to the graphics problem being considered at the time.

Programming before computer graphics. Two schools where computer programming has been taught prior to computer graphics are The Ohio State University (LaRue, 1980) and Clemson University (Ryan, 1980). Both of these programs will be discussed.

At Ohio State University, LaRue (1980) reported that for the past ten years, the Engineering Graphics Department has taught two required courses for all engineering students. The first was EG 110, General Engineering Graphics (5 quarter credits)--this was usually taken during the freshman year. EG 200, Introduction to Digital Computing and Engineering Analysis (3 credits), was usually taken by sophomores. This sequence of two courses is being revised so that three classes will be taught during the freshman year and interactive computer graphics will be used in all three courses. Generally, the new sequence will be descriptive geometry and sketching, programming, and the remainder of

graphics. LaRue reported that the Dean of Engineering suggested this revision and was very supportive of incorporating interactive computer graphics into the curricula.

At Clemson University, Ryan (1980) reported that computer-aided engineering graphics (3 semester credits) followed a class in engineering graphics. A computer programming course was taken concurrently with the first graphics course. During the first graphics course, the emphasis was on modern engineering graphics concepts. However, the last unit of the semester (approximately one week) should be an introduction to computer graphics.

The first course should contain as little programming as possible. The second course dealing with computer graphics should merge topics like descriptive geometry with an introductory statics using computer graphics output in problem solutions. Graphics programming techniques should be part of this course. (Ryan, 1980, p. 367)

Concerning topics to teach, Ryan said that "the topics of computer graphics are almost endless, depending upon the instructors [sic] background and area of speciality" (p. 368). He advocated the use of computer graphics very strongly: "Let us all remember that graphics is graphics and that is never going to change--but the methods for producing graphics has already changed in most industries. It is time to catch up again!" (p. 368).

In an article entitled "Why Engineers Can't Communicate," Levens (1982) suggested that a two unit course in computer graphics should follow the required engineering graphics class. He briefly mentioned that an introduction to computer graphics should be the last topic studied in the required first graphics course. For certain majors,

civil and mechanical engineers, a second required graphics course should follow the computer course. Although he did not clearly state it, the assumption is that the computer graphics course would include programming.

Computer graphics combined with programming. Computer programming has been taught at some schools at the same time computer graphics was introduced. Often the authors stressed that the programming was minimal for this introduction.

At the University of Illinois at Chicago Circle, the procedure used in implementing computer graphics in the two quarter hour freshmen engineering graphics classes was described in three separate articles (Mosillo, 1973, 1974; Mosillo & Wolf, 1976). Mosillo stressed that their purpose was to teach graphics and not programming, and that the computer should be used as a tool at this stage of the students' education. Over the years, they have simplified the amount of student involvement in the computer languages. The computer is used mainly "to motivate and teach the basic principles of multiview projections" (Mosillo & Wolf, 1976, p. 37). Mosillo thought that the instructor should have had experience in programming, but it was not necessary for the students to have had this experience before using the computer (1974).

Coppinger (1974) from Texas A&M University explained how a minimal amount of FORTRAN programming was used in a one-week introduction to computer graphics. The computer graphics introduction was part of a freshmen engineering graphics class. The amount of programming was limited to only the topic being taught at the time.

Zsomber-Murray (1977) described a one semester freshmen engineering graphics course taught at McGill University in Montreal which included 25 percent computer graphics content using a minimal amount of programming. During the last three weeks of a 13 week course, seven computer graphics exercises were assigned to be worked as group projects. Only one of these seven exercises required writing a program (FORTRAN). In five of the exercises, the students prepared a job control card and the data cards to operate the card reader. There was one problem involving interactive graphical input. The topics included labeling, plotting graphs, digitizing graphical data, generating a perspective view, generating successive auxiliary views, contour mapping, and mechanism animation. Zsomber-Murray added that the computer was used to improve teaching efficiency by requiring less time of the professor for teaching procedures and thus allowing more time for the graphic principles.

At the University of Nebraska at Lincoln, DeLorm and Smith (1975) described two freshmen courses that were required for most students-- Engineering Communication I and II. At this school, either of the two courses could be taken first. Communications I dealt with basic traditional graphics; included were descriptive geometry, orthographic projection, geometric construction, auxiliary views, dimensioning, threads and fasteners, sectioning, and team design projects. About 10 percent of the assignments were drawn with traditional instruments, while the remaining exercises were engineering sketches. Communications II was FORTRAN IV programming which included "hands-on"

experience with the computer plotter. When this course was first started in the mid-1960's, the faculty thought theirs was the only university offering "hands-on" computer graphics. Since the students were allowed to take either course first, the students could have programming and computer graphics either before or after traditional graphics.

Content

As previously stated, the basic drawings in engineering graphics contain pictorial drawings (isometrics and obliques), orthographic projection, working drawings, graphs and charts (Sell, 1977). DeLorm and Smith (1975) included most of the same content for their traditional approach to Engineering Communications I. The topics which they included were descriptive geometry, orthographic projection, geometric construction, auxiliary views, dimensioning, threads and fasteners, sectioning, and team design projects. Edwards (1977) in his dissertation, Computer Applications to Engineering Design and Drawing with Basis for Course Content in Teaching Computer Graphics, suggested topics that should be offered in beginning drafting courses that were intended to train computer graphics personnel. He listed charts and graphs, descriptive geometry, orthographic projections, detail and assembly working drawings, dimensioning and tolerancing as possible topics.

Barr and Demel (1980) suggested suitable topics for a computer graphics laboratory. They included many of the same topics mentioned by others previously: "Construction of geometric objects; orthographic

projection; pictorial drawings; dimensioned engineering drawings; charts and graphs; and schematics and diagrams" (p. 828).

Ryan (1980) was much broader regarding the topics suitable for computer graphics. He mentioned that the topics depended on the background of the instructor.

Hartman (1981) described an introduction to computer graphics which was used in the students' design projects. The user-oriented software included graphics, computer sketching, text editing, orthographics, and isometric views. Also included were analysis "packages" to use in the design process. Included were lathe, mill, weld, kinematics, and others.

Computer Graphics in Courses Above the Freshman Level

When computer graphics was taught above the freshman level, normally prerequisites of computer programming and engineering graphics were employed. At this higher level, computer graphics was used in two settings. Courses of computer graphics were taught at several schools. Other professors incorporated computer graphics as a tool in more specialized courses.

Computer Graphics as a Major Portion of the Course

Moche1 (1970) from the University of Virginia described a junior-level course that had ALGOL programming as its only prerequisite. The first semester it attracted a diverse group of students which included one or more students from every undergraduate degree granting

department at this university. The main areas of the course were geometry of projection, matrix transformations, and data presentation. The students had a weekly assignment on the x-y plotter. The purpose of the course was "not to teach programming as an end in itself" (p. 54), but to acquaint students with applications of computer graphics.

West (1972) described a graduate computer graphics course that was offered at the Moore School of Electrical Engineering at the University of Pittsburgh. Several years prior to offering this course, computer graphic techniques had been used in several research projects at this school. This course also served as an introduction to engineering for students from other disciplines who wanted to pursue computer graphics; thus, there was little reference to other graduate computer science courses. The only prerequisite was a working knowledge of FORTRAN.

Kearns (1973) from The Ohio State University discussed a computer graphics package that was suitable for advanced graphics. It was not clear whether or not the package had been implemented. He listed the subroutines that "produce orthographic, isometric, axonometric and perspective drawings, in standard sizes, complete with border, and title block" (p. 12). Kearns also included a list of other features that would be desirable in a more comprehensive package. These included plotting of curved shapes, implementation of a complete set of line symbols, routines for other drafting symbols, solution of the hidden line problem, treatment of overlapping lines, and full dimensions of three-dimensional drawings.

An elective computer graphics course at the junior level was offered at Iowa State University (Dowling, 1976). It was open to non-engineers and had only basic FORTRAN programming as a prerequisite. The four major areas covered were passive graphics, interactive graphics, applications, and individual project. Since the school did not have the hardware for interactive graphics, students made oral reports to the class based upon their study of current professional journals.

Demel and Coppinger (1978) at Texas A&M University described how programming and computer graphics could be taught together in an upper level course. Their method also helped the instructor who was not skilled in programming. Only enough programming steps to solve one graphical problem each time were used in the classroom lesson.

One dissertation in the computer graphics field was that of J. C. Brown, A Comparative Study Leading to the Creation of a Model for Computer Graphics Instruction in Post-Secondary Schools of Texas (1972). Demel and Coppinger based their course on Brown's research and modified it for the available hardware (Keith, 1978). As a result of his research, Brown recommended that the prerequisites for a computer graphics class should include engineering graphics--especially orthographic projection and pictorial representation, and a working knowledge of FORTRAN programming. He recommended that the instructor "should be allowed sufficient time to become familiar with the programming requirements peculiar to the equipment used to support the course work" (p. 69). Topics that Brown included in his model for a computer graphics course were: familiarization with the development and equipment of computer graphics, review of FORTRAN, charts, graphs,

tolerances, circles, orthographic projection, oblique drawings, matrices, pictorial drawings, and animation.

Another dissertation in the field of computer graphics was that of Edwards (1977) from the University of Houston, Computer Applications to Engineering Design and Drawings with Basis for Course Content in Teaching Computer Graphics. The topics which Edwards recommended have been mentioned previously: charts and graphs, descriptive geometry, orthographic projections, detail and assembly working drawings, dimensioning and tolerancing.

Applications of Computer Graphics Above the Freshman Level

Barr (1982) stated that computer graphics has much potential in upper level classes.

For upper division engineering courses, computer graphics should be incorporated as a routine procedure for solving and displaying solutions to a wide variety of engineering problems. The list of engineering courses that can use computer graphics as a problem solving tool is extensive. Particular examples can be drawn from kinematics, control theory, circuit analysis, machine design, construction engineering, and process control, to name a few. The guiding concept is that computer graphics offers an intuitive dimension to problem solving that is now needed for engineering design problems that are becoming more complex and numerically oriented. (p. 173)

More specific examples of applications of computer graphics may be referred to in the following examples. Otis (1971) from Case-Western Reserve University discussed a system "which incorporated a computer and plotter to draw stereoscopic [sic] pairs of vector loops" (p. 35) which aids physicians in heart disease analysis. A FORTRAN IV program was used to make perspective drawings of the vectorcardiogram

loops which were next drawn by a plotter. Otis mentioned that further research needs to be completed to determine if this technique would be useful as a teaching aid for electrocardiography and vectorcardiography. Raczowski (1973) of Texas A&M University discussed a method to produce an animation of linkage motion. Computer-generated drawings of a linkage system in numerous positions were drawn by a Gerber plotter. These plotted drawings were then photographed to make a short movie for instructional purposes. Halpern (1970) discussed two computer programming languages, SEL and SELMA, which were developed at the University of Michigan to be used for experimental and instructional use of computer graphics. The programs allowed the user to experiment easily with the drawings on the computer screen through the use of a light pen.

Erdman and Frohrib (1975) from the University of Minnesota described several computer graphics packages. Included were rigid bar on finite impedance supports, a simplified automobile model, four-bar linkage analysis, and slider crank mechanism with a flexibly-attached slider. Some of these pre-programmed packages did not require any knowledge from the student user about how the programming had been accomplished. Displays of computer-generated graphics were used to illustrate different possible solutions when the input was varied by the user.

A successful example of computer graphics in engineering education research was completed at Washington University; six CAD programs were developed on a microcomputer system to be used in a third year civil engineering course. This was the basis for a master's thesis in civil

engineering education. There were three criteria that the teaching aid must meet (Charles, Galambos, & Gould, 1982).

1. An engineering design aid should give students accelerated hands-on experience with the design process as applied to a particular problem.
2. It should enable engineering students to solve large problems rapidly by automatically performing the repetitive and tedious design calculations.
3. The teaching of the basic concepts of design and the supportive structural analysis techniques are best performed in the classroom so that, from the teaching-aid viewpoint, all theory was assumed to be prior knowledge. (p. 792)

The authors found CAD was an effective teaching aid in engineering design, and that software could be developed for use on the low cost microcomputer.

Summary

The review of literature pointed out that engineering educators recognized that computer graphics needed to be introduced to beginning engineering students at some point in the curriculum. Many suggested engineering graphics as a logical place to combine the two processes of graphics: the traditional methods of manual drawing and the newer technology of computer graphics. In an introductory setting, computer programming should be minimized and probably eliminated from computer graphics. Above the introductory level of computer graphics, programming has been handled differently at various schools. Computer graphics can be considered an engineering tool for the engineer at all levels and an instructional tool for the engineering graphics educator.

CHAPTER III

METHODOLOGY

The purpose of this study was to determine if the use of a combination of manual drawing and computer graphics is an efficient way to teach engineering design graphics and to serve as an introduction to computer graphics for the beginning engineering student. Chapter III will explain how the study was conducted.

Subjects

The population for this study was composed of all students enrolled in Engineering Design Graphics (EDG) 105 during the fall semester at Texas A&M University. The sample was one EDG class selected from the population on the basis of three conditions. First, the professor of the class had to be competent to teach both computer graphics and the regular EDG 105 classes. Secondly, the class had to have the least scheduling conflict with the other computer graphics classes. Thirdly, an assistant had to be available during the same class time. Students in the selected class were randomly assigned to either the control or treatment group using the technique of a table of random numbers as discussed by Isaac and Michael (1979). Both the treatment group and the control group initially contained 19 students each. Because of absences of some students at various times during the study, the size

of the treatment group ranged from 19 to 15 and the size of the control group also ranged from 19 to 15.

Exercise Content

The course syllabus for EDG 105 had already been established prior to this study. Therefore, topics had to be selected which would be appropriate for this study without making unnecessary changes in existing routines in the established course.

The exercises selected for the study were those which met three criteria. First, the topics selected were to be basic representative topics from an engineering graphics course. Second, the software available for the initial programming needed to be readily available to eliminate long delays in setting up the study. Qualified EDG faculty made modifications of in-house programs that had been previously used for other purposes. Third, in order for the study not to be disruptive to the progress of the regularly scheduled class, the arrangement of the topics on the pre-existing course syllabus was considered. Both the first week and the last week of the semester in which the course was taught were avoided because of indefinite class rosters and interference with the end of semester activities. The topics to be used needed to be spaced at approximately one-week intervals on the already-existing course syllabus in order to allow sufficient flexibility for presentation of topics and hardware maintenance of the computer facilities, if necessary. Using the three mentioned criteria, five topics were selected: bar graph, breakeven graph, orthographic projection, isometrics, and obliques. The treatment

(which will be discussed later) was administered regarding these five topics as they occurred approximately one per week on the course syllabus during weeks three through six of the semester. Thus, only these representative topics of the course were selected-- not everything on the regular course syllabus was used for this study.

Measures

A closely monitored, comprehensive examination consisting of 100 multiple choice questions covering all topics taught is administered to all students in the Engineering Design Graphics Department. This examination is routinely administered during the first and last weeks of the semester. Weekly quizzes are also given routinely to all students during the last class meeting of each week. These weekly quizzes are normally made for the use of the entire department who make two versions of the 15 to 20 minute quiz. All students in the EDG department take either version A or B depending on the choice of their professor. The weekly quiz contains approximately seven multiple choice questions worth ten points each regarding material covered during the week and the remaining 30 points on the quiz are construction problems which are drawn in the traditional manner with drafting machines, triangles, and pencils.

Three measures were used in the study: the weekly departmental quizzes (explained in the preceding paragraph), the standard departmental comprehensive examination, and a computer graphics test. Five

of the 12 weekly quizzes contained topics that were included in this study--these were the quizzes for weeks three through seven. The content of the weekly quizzes and of the comprehensive test was the standard departmental instrument. No questions were altered or added; however, during the analysis of both the weekly quizzes and comprehensive examination, some questions were deleted which were not pertinent to topics covered in this study. The computer graphics test was designed for this study and was reviewed by several qualified professors before it was administered. The computer graphics test contained two parts: the first part covered broad conceptual facts regarding computer graphics. The second part dealt with the attitude of the student regarding the use of computer graphics. Both parts of the computer graphics test may be referred to in Appendix A.

Method of Administration

Both the control and treatment groups received the same lecture by their professor on each of the selected topics. For each topic in the EDG classes, there is usually an initial exercise (drawing problem), normally followed by two or three additional (supplementary) exercises which serve to further establish this same basic concept with the student. Frequently these following (supplementary) exercises are slightly more complex than the first one. In the study, each individual student in the class (both control and treatment groups) drew the first exercise for each topic assigned in the study by using traditional manual methods involving drafting machines, triangles, and

plates (workbook sheets). For one of the subsequent exercises on each selected topic, the class was split into the control and treatment groups. At this time the control group stayed in the classroom with their professor and each individual drew the supplementary plate (exercise) using traditional manual methods. While the control group was drawing the supplementary plate manually, the treatment group went to the computer room and used the computers to draw a similar problem on the same topic. Examples of the assignments for the treatment group are in Appendix B, and for the control group are in Appendix C.

When the treatment group worked with the user-oriented computer graphics, the students typed their response to questions appearing on the cathode ray tube (CRT) which asked how the student wanted to have various aspects of the drawing constructed. The drawing was then produced line by line on the CRT screen based on information supplied by the student. Three CRTs were available to the treatment group. Depending on maintenance of the hardware, one or two plotters were also available. If the student selected a CRT with an available plotter, the student then also received a paper copy of the drawing which was produced by the plotter using a felt-tipped pen.

As previously stated, the treatment group drew their supplementary exercises with user-oriented computer graphics; the exercises required no previous programming or computer experience. Two teachers supervised the control and treatment groups with the professor for the class staying in the regular classroom with the control group. On the days of the study, the assistant stayed in the computer room to give directions as needed. A pilot study was conducted during the second

semester of summer school 1981 to check the execution of the computer graphics exercises and to resolve unforeseen problems according to the recommendations of Borg and Gall (1971).

As a placebo, the control group was told early in the semester that they would have the opportunity to use the computer graphics facilities before the semester ended; thus, after all data were collected, the control group knew they would have this opportunity. This was designed to prevent contamination between the two groups; however, there was little request from the control group to take advantage of the opportunity.

The amount of time (in minutes) that each student spent on each of the five exercises was recorded to check for efficient use of time. The students in the control group recorded their time on each plate in the space provided for time before they turned in the plate to their professor. Those students in the treatment group told the assistant how long he or she spent at the CRT; their time was then recorded in a record book by the assistant before the students in the treatment group left the computer room. A few students in the control group neglected to record their time and had to be asked later to approximate it.

As previously mentioned, the EDG Department has a standard comprehensive examination. This standard departmental comprehensive test was given as a pre-test and a post-test for this study. The pre-test was administered during the first week of the semester and the post-test was administered during the next to the last week of the

semester. Giving the comprehensive test at these two times is routine procedure in the EDG Department in all EDG 105 classes. For the computer graphics test, the pre-test was administered before the class started any of the exercises for the study. Post-test I was administered during the week that the exercises for the study were completed (during week six of the semester); post-test II was administered the same day as the comprehensive examination.

Analysis

The data were evaluated by analysis of variance because of the nature of the collected data. In all cases, the independent variable was the treatment variable which indicated whether the subjects were in the control or treatment group. The 0.05 level of significance was used in testing the hypotheses.

Hypotheses

Hypothesis one was used to determine weekly achievement. The type of analysis used for hypothesis one was a single classification analysis of variance (ANOVA). First, this method was used for each of the five total quiz scores; it was also used on the average of the five total scores. Next, the same technique was used test by test on the pertinent questions from each of the five quizzes.

Hypothesis two was used to determine overall retention. A 2 x 2 factorial analysis of variance technique was used. The primary item of interest was to determine if the interaction between the treatment

and the trials (pre-test and post-test) was significant. Similar to hypothesis one, this analysis was made first for each test with the total comprehensive scores and again for each test with the extracted pertinent questions.

A 2 x 3 factorial analysis of variance with repeated trials on the second factor was used for hypothesis three. The second factor was trials: pre-test, post-test I, and post-test II. As in hypothesis two, the main item of interest was to determine if the interaction between the treatments and trials was significant.

Time

A single classification ANOVA was used to determine if there was a significant difference in the amount of time (in minutes) spent by the two groups on the selected exercises of the study. As previously mentioned, time was used to check the efficiency of the two groups.

CHAPTER IV

FINDINGS

Data for this chapter were obtained from the measurements taken of the sample in one EDG 105 class at Texas A&M University during the fall semester 1981. Appropriate forms of analysis of variance were used for the data analysis. In all cases, the independent variable was the treatment variable which indicated whether the subjects were in the treatment (computer graphics) group or control (manual) group.

Missing Data

As previously stated in Chapter III, the total sample originally was composed of 38 students. On different occasions, various students were absent when different tests were being administered. If a student was absent and missed only one out of the five weekly quizzes, then the average (mean) score of the four quizzes which were taken by the student was used as a substitute score for reporting and analyzing the data. Thus, if only one quiz was missed by a student, a substitution was made and the resulting sample size does not reflect the missing data. However, if two or more quizzes were missed by one student, then no substitutions were made and the number of students in the sample at the time will reflect these absences; and, the degrees of freedom will also reflect the resulting smaller sample size. The procedure just described was also used for students whose time (in minutes) on the five assigned

exercises for this study was unavailable due to absenteeism.

When the quiz questions unrelated to this study were deleted and only the remaining pertinent questions were used in reporting and analyzing the data, no substitutions were made for specific quiz questions regardless of how many quizzes were missed by an individual student. The number of subjects in the sample for a particular quiz might be larger, therefore, when all questions in the quiz are considered than when only the pertinent questions are considered. Various tables later in the chapter will reflect different sample sizes (possibly on the same quiz) due to the methods just described for treating missing data caused by absenteeism.

Weekly Quizzes

Out of a total of 12 weekly quizzes on the well-established course syllabus for the entire semester, five quizzes were considered appropriate to the study which contained material (multiple choice questions and construction drawings) which covered the five selected and previously named topics for this research. The quizzes useful to this study were quizzes three through seven. The questions on these five quizzes were considered in two major ways. First, all questions on each of these five quizzes were used for measuring weekly achievement on all material presented during the week. Second, because the quiz covered the material taught for an entire week, part of the weekly quiz questions dealt with material which was not a part of this research. The questions unrelated to this study were, therefore, deleted, and only the pertinent questions were considered on each of the

five quizzes for measuring short-term retention of the material relating specifically to this study.

Table 1 shows the means of weekly quizzes three through seven when all questions were considered for the treatment and control groups. From this table, it can be seen that in quizzes four, five, six, and seven, the treatment group maintained the higher mean score. The scores varied the least and had the smallest range on quiz four, where both groups also showed the highest mean score of the five quizzes. Both groups also scored lowest on the same quiz (quiz five). However, on quiz five, the largest difference between the mean score of the treatment group and the control group appeared--12.38 points being the difference between the two group's mean scores.

Table 1
Table of Mean Score
for All Weekly Quiz Questions

| Quiz | Treatment | | | Control | | | Max. Pts. Possible |
|------|-----------|-------|--------------|---------|-------|--------------|--------------------------|
| | N | mean | std. dev. | N | mean | std. dev. | |
| 3 | 19 | 74.74 | 14.67 | 18 | 81.67 | 13.17 | 100 |
| 4 | 18 | 92.11 | 7.68 | 19 | 89.47 | 8.87 | 100 |
| 5 | 18 | 72.22 | 14.06 | 19 | 59.84 | 16.40 | 100 |
| 6 | 18 | 78.33 | 16.63 | 19 | 71.58 | 15.19 | 100 |
| 7 | 18 | 80.56 | 12.09 | 18 | 75.11 | 10.03 | 100 |

Table 2 shows information similar to Table 1 (p. 41), except that on Table 2, only the pertinent questions (previously described) from each of the quizzes three through seven were considered. Also shown in this Table 2 are the maximum points possible on the extracted pertinent questions. These maximum points vary from one quiz to another because each quiz originally contained a possible maximum of 100 points before the pertinent questions were extracted, and the point count for those questions which were retained as pertinent to this study varied depending on the quiz. Table 2 shows again that the treatment (computer graphics) group had a higher mean score than the control (manual) group for quizzes four, five, six, and seven. Quiz

Table 2
Table of Mean Scores
for Pertinent Weekly Quiz Questions

| Quiz | Treatment | | | Control | | | Max. Pts. Possible |
|------|-----------|-------|--------------|---------|-------|--------------|--------------------------|
| | N | mean | std. dev. | N | mean | std. dev. | |
| 3 | 19 | 30.53 | 7.43 | 18 | 34.72 | 6.06 | 40 |
| 4 | 18 | 54.33 | 6.07 | 19 | 53.68 | 7.00 | 60 |
| 5 | 17 | 54.41 | 13.91 | 18 | 46.11 | 13.46 | 80 |
| 6 | 17 | 30.29 | 10.07 | 19 | 29.47 | 9.41 | 40 |
| 7 | 15 | 46.33 | 7.90 | 15 | 42.67 | 7.29 | 55 |

three was the only quiz in which the control group's mean score was higher than the treatment group's mean score, both when all questions were considered (Table 1, p. 41) and when only the pertinent questions were considered (Table 2, p. 42). Although not shown as percentages in Table 2 (p. 42) when using only the pertinent questions, the percentage of the maximum points possible was again highest for both the treatment and control groups on quiz four as it was on quiz four for both groups when all questions were used on the quizzes (Table 1, p. 41). In Table 2 (p. 42), the highest score for the treatment group was 54.33 of a possible 60 points (90.6%), and 53.68 of a possible 60 points (89.5%) was the highest score for the control group.

Null hypothesis number one, that there is no significant difference in achievement between students who use a combination of both manual and user-oriented computer graphics exercises, and by students who use only manual exercises for selected questions on departmental weekly quizzes, was tested by using a one-way analysis of variance for each of the mean scores on the five weekly quizzes used in this study. One-way analysis of variance (ANOVA) was used in three ways for null hypothesis one. First, ANOVA was used for each of the separate quizzes three through seven when using all questions on each quiz. The ANOVA of mean scores received on quizzes containing all questions are summarized in Table 3. The degrees of freedom (df) are unlike in some cases because of missing data due to absenteeism (which was discussed previously in this chapter). As noted in Table 3, quiz five was the only quiz that showed a significant difference in mean test scores (at the .05 level) between the treatment and control group. As can be seen for quiz five

Table 3
Analysis of Variance Summary Table for
All Weekly Quiz Questions

| Source | df | MS | F | p |
|-----------|----|---------|------|---------|
| Quiz 3 | | | | |
| Treatment | 1 | 443.89 | 2.28 | 0.1367 |
| Within | 35 | 194.96 | | |
| Quiz 4 | | | | |
| Treatment | 1 | 64.27 | 0.93 | 0.3433 |
| Within | 35 | 69.10 | | |
| Quiz 5 | | | | |
| Treatment | 1 | 1416.67 | 6.05 | 0.0180* |
| Within | 35 | 234.28 | | |
| Quiz 6 | | | | |
| Treatment | 1 | 421.72 | 1.67 | 0.2025 |
| Within | 35 | 252.93 | | |
| Quiz 7 | | | | |
| Treatment | 1 | 266.77 | 2.16 | 0.1472 |
| Within | 34 | 123.42 | | |

Notes: *significant at .05 level
 $F(1,34) = 4.13$ is required for .05 significance
 $F(1,35) = 4.12$ is required for .05 significance

in Table 1 (p. 41), the mean score of the treatment group was more than 12 points higher than the control group. This indicates higher achievement on the lessons evaluated by this quiz on the part of the treatment group.

One-way ANOVA was used in a second way in regard to null hypothesis one. All scores for quizzes three through seven were combined first for the treatment group and then for the control group. ANOVA was then performed after the scores were combined for each group. The results are shown in Table 4, and indicated that there was no significant difference in the scores between the treatment and control groups. Therefore, it can be concluded that the treatment had no significant effect on the overall (combined) achievement as indicated by the quiz scores.

Table 4
Analysis of Variance Summary Table for
Combined Quizzes 3 Through 7

| Source | df | MS | F | p |
|-----------|----|----------|------|--------|
| Treatment | 1 | 18000.00 | 2.66 | 0.1084 |
| Within | 34 | 6764.03 | | |

Note: $F(1,34) = 4.13$ is required for .05 significance

One-way ANOVA was used a third way for null hypothesis one. The quiz questions unrelated to this study were deleted, leaving only the questions pertinent to the study for each of the five quizzes. ANOVA was then performed quiz by quiz on the remaining pertinent questions on quizzes three through seven. As shown in the summary table (Table 5), there was no significant difference between the scores of the treatment and control groups on any of the five quizzes in the study when only the pertinent questions were considered. As previously explained, the degrees of freedom (df) in Table 5 varied due to absenteeism and the manner in which absenteeism was handled.

Based on the data analysis, there was no significant difference between the treatment and control groups in their achievement on the weekly quizzes. Therefore, there was no reason to reject hypothesis one.

Comprehensive Examination

As mentioned in Chapter III, the departmental comprehensive examination, composed of 100 multiple-choice questions, was given as a pre-test at the beginning of the semester and as a post-test at the end of the semester. Giving the comprehensive examination at these two times was a routine procedure for all EDG 105 classes at Texas A&M University.

As with the weekly quizzes, all questions on the comprehensive examination were considered first. Next, the questions unrelated to this research were deleted, and the remaining questions, pertinent to this research, were considered. The researcher made a list of test

Table 5
Analysis of Variance Summary Table for
Pertinent Weekly Quiz Questions

| Source | df | MS | F | p |
|-----------|----|--------|------|--------|
| Quiz 3 | | | | |
| Treatment | 1 | 162.75 | 3.52 | 0.0658 |
| Within | 35 | 46.24 | | |
| Quiz 4 | | | | |
| Treatment | 1 | 3.90 | 0.09 | 0.7628 |
| Within | 35 | 43.09 | | |
| Quiz 5 | | | | |
| Treatment | 1 | 602.37 | 3.22 | 0.0784 |
| Within | 33 | 187.03 | | |
| Quiz 6 | | | | |
| Treatment | 1 | 6.04 | 0.06 | 0.7975 |
| Within | 34 | 94.66 | | |
| Quiz 7 | | | | |
| Treatment | 1 | 100.84 | 1.75 | 0.1944 |
| Within | 28 | 57.74 | | |

Notes: $F(1,28) = 4.20$ is required for .05 significance
 $F(1,33) = 4.14$ is required for .05 significance
 $F(1,34) = 4.13$ is required for .05 significance
 $F(1,35) = 4.12$ is required for .05 significance

questions for both the weekly quizzes and the comprehensive examination which pertained only to topics in this study. These listings were approved by a jury of qualified, experienced EDG faculty.

The mean scores for the two groups, when all questions were used on the comprehensive examination, are shown in Table 6. As shown in the table, the treatment group, with a pre-test mean score of 35, scored lower than the control group with a pre-test mean score of 39. However, the treatment group scored higher than the control group on the post-test. This resulted in a higher mean score of 74.89 for the treatment group and a 68.33 mean score for the control group when all questions on the comprehensive examination were considered.

Table 7 shows the mean scores for the treatment and control groups when only the pertinent questions on the comprehensive examination were considered. From the total of 100 questions on the entire examination, only 18 questions were concerned with subject matter used in this research. Therefore, the mean scores in Table 7 are based on a possible 18 points. The same pattern that developed when the entire examination results were analyzed was repeated in this instance--the control group mean score was higher than the treatment group on the pre-test, but the treatment group mean score was higher than the control group on the post-test. The control group gained approximately five points while at the same time the treatment group gained over seven points from the pre-test to the post-test. The treatment group, therefore, showed greater achievement of engineering graphic principles covered in the study over the time span between the pre-test and post-test.

Null hypothesis number two, that there is no significant difference in the achievement (gain or loss from pre-test to post-test scores) on the overall course material between students using a combination of

Table 6
 Mean Scores for
 Comprehensive Exam--All Questions

| Group | Pre-test | | | Post-test | | | Max. Pts. Possible |
|-----------|----------|---------------|--------------|-----------|---------------|--------------|--------------------------|
| | N | mean score | std. dev. | N | mean score | std. dev. | |
| Treatment | 18 | 35.00 | 6.53 | 18 | 74.89 | 8.01 | 100 |
| Control | 18 | 38.67 | 6.31 | 18 | 68.33 | 6.75 | 100 |

Table 7
 Mean Scores for
 Comprehensive Exam--Pertinent Questions

| Group | Pre-test | | | Post-test | | | Max. Pts. Possible |
|-----------|----------|---------------|--------------|-----------|---------------|--------------|--------------------------|
| | N | mean score | std. dev. | N | mean score | std. dev. | |
| Treatment | 18 | 5.11 | 2.11 | 18 | 12.33 | 2.43 | 18 |
| Control | 18 | 5.94 | 1.80 | 18 | 10.89 | 2.63 | 18 |

manual and user-oriented computer graphics exercises and by students using only manual exercises as measured by the standard departmental comprehensive test, was tested using a 2 x 2 factorial analysis of variance (ANOVA) procedure. The first factor was treatment--treatment group and control group. The second factor was trials--pre-test and post-test. Similar to hypothesis one, ANOVA was employed first for all questions on the comprehensive examination and next for the extracted pertinent questions from the examination.

When test scores for all questions on the comprehensive examination were considered, and ANOVA was performed (Table 8), the interaction between the treatment and trials was significant at the .01 level. This interaction in favor of the treatment group is shown graphically in Figure 1. Thus, it can be seen that the treatment group had the lower pre-test mean score, but they had a higher gain as indicated by the greater slope of the treatment line and the higher mean score for the post-test.

When only the test scores on the comprehensive examination for questions pertinent to this study were considered, and ANOVA was employed, the results are summarized in Table 9. From this table, it can be seen that the interaction between the treatment and trials was significant at the .05 level. This interaction can be seen graphically in Figure 2 where it can be seen that the greater gain was in favor of the treatment group. Similar to the pattern shown in Figure 1, the interaction shown in Figure 2 also shows that the treatment group again started with the lower mean score

Table 8
Analysis of Variance Summary Table for
Comprehensive Exam--All Questions

| Source | df | MS | F | p |
|-------------|----|----------|--------|-----------|
| Between | | | | |
| Treatment | 1 | 37.55 | 0.67 | 0.4243 |
| Error | 34 | 56.11 | | |
| Within | | | | |
| Trials | 1 | 21770.86 | 551.61 | 0.0000*** |
| Interaction | 1 | 470.18 | 11.91 | 0.0018** |
| Error | 34 | 39.47 | | |

Notes: **significant at .01 level
***significant at .001 level
F(1,34) = 4.13 is required for .05 significance

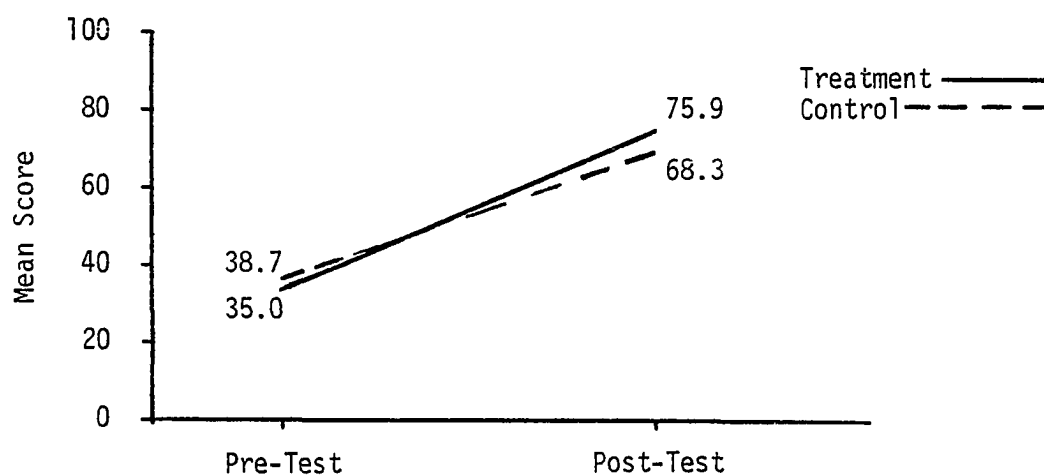


Figure 1

Interaction Between Treatment and Trials for
Comprehensive Exam--All Questions

Table 9
 Analysis of Variance Summary Table for
 Comprehensive Exam--Pertinent Questions

| Source | df | MS | F | p |
|-------------|----|--------|--------|-----------|
| Between | | | | |
| Treatment | 1 | 1.68 | 0.26 | 0.6168 |
| Error | 34 | 6.37 | | |
| Within | | | | |
| Trials | 1 | 666.12 | 171.54 | 0.0000*** |
| Interaction | 1 | 23.35 | 6.01 | 0.0185* |
| Error | 34 | 3.88 | | |

Notes: *significant at .05 level
 ***significant at .001 level
 $F(1,34) = 4.13$ is required for .05 significance

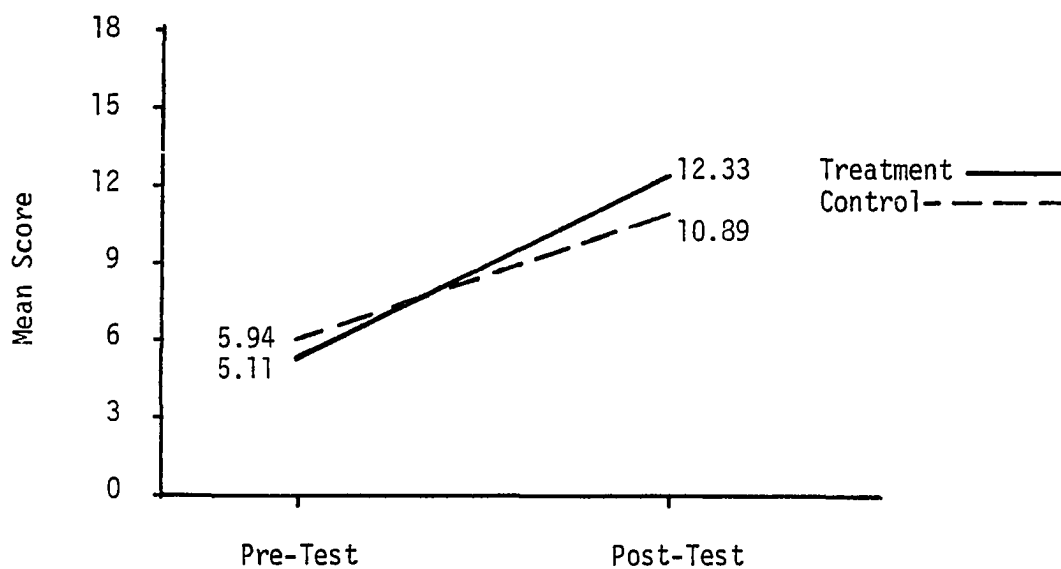


Figure 2

Interaction Between Treatment and Trials for
 Comprehensive Exam--Pertinent Questions

than the control group on the pre-test, but the treatment group showed a higher gain and had a higher post-test mean score than the control group when only the pertinent questions on the comprehensive examination were considered.

Based on the analysis of the data for null hypothesis two, there was a significant interaction between the treatment and the trials in favor of the treatment group on the comprehensive examination. Therefore, hypothesis two was rejected.

Computer Graphics Test

A computer graphics test composed of two parts (as mentioned in Chapter III) was prepared and administered for this study (see Appendix A). The first part of the test contained ten multiple choice questions concerned with basic concepts related to computer graphics. The second part was a survey to determine the students' attitude toward using computer graphics. This second part contained ten comments to which students responded by replying A = strongly agree, B = agree, C = neutral, D = disagree, and E = strongly disagree. Both parts of the computer graphics test were administered three times--as a pre-test, post-test I, and post-test II.

Computer Graphics--Subject Matter

Table 10 shows the mean scores of the treatment and control groups on the first part (subject matter) of the previously described computer graphics test. As on most of the other measurements in this research,

the control group had a higher mean score than the treatment group on the pre-test. The control group maintained the same mean score on the post-test I and scored slightly higher on post-test II than on the other two administrations of the test. The treatment group attained their highest mean score on post-test I with a mean score of 75.00 and scored somewhat lower on the post-test II with a mean score of 69.44. It is apparent that the treatment group tended to forget some of the material relating to computer graphics over a time span of approximately seven weeks.

Table 10
Mean Scores for
Computer Graphics--Subject Matter

| Group | N | Pre- test | std. dev. | N | Post- test I | std. dev. | N | Post- test II | std. dev. |
|-----------|----|--------------|--------------|----|-----------------|--------------|----|------------------|--------------|
| Treatment | 18 | 28.33 | 18.23 | 18 | 75.00 | 15.81 | 18 | 69.44 | 17.65 |
| Control | 18 | 32.78 | 15.65 | 18 | 32.78 | 15.65 | 18 | 38.89 | 20.26 |

Null hypothesis three, that there is no significant difference in achievement of computer graphic principles by students using a combination of manual and user-oriented computer graphics exercises and by

students using only manual exercises as measured by a special computer graphics achievement test given as a pre-test, post-test I, and post-test II, was tested using a 2 x 3 factorial analysis of variance (ANOVA) procedure. The second factor was trials in which three levels were used: pre-test, post-test I, and post-test II. As indicated in Table 11, the interaction between the treatment and trials was significant at the .001 level. This interaction in favor of the treatment group is also shown graphically in Figure 3. Throughout the three administrations of the test, the control group mean scores remained relatively unchanged compared to the treatment group. The treatment group gained over 46 points between the pre-test and post-test I, but then scored slightly lower on post-test II. However, the treatment group's mean score was still more than 30 points higher than the control group's mean score on post-test II. Thus, after the administration of the treatment, the treatment group performed much better than the control group on the computer graphics test.

Based on the data analysis for hypothesis three, there was a significant interaction between treatment and trials in favor of the treatment group on the computer graphics test. Therefore, hypothesis three was rejected.

Computer Graphics--Attitude Survey

The second part of the computer graphics test, as mentioned previously, was an attitude survey regarding the use of computer graphics.

Table 11
 Analysis of Variance Summary Table for
 Computer Graphics--Subject Matter

| Source | df | MS | F | p |
|-------------|----|----------|-------|-----------|
| Between | | | | |
| Treatment | 1 | 14008.50 | 25.70 | 0.0001*** |
| Error | 34 | 545.15 | | |
| Within | | | | |
| Trials | 2 | 6612.12 | 37.60 | 0.0000*** |
| Interaction | 2 | 5308.14 | 30.18 | 0.0000*** |
| Error | 68 | 175.87 | | |

Notes: ***significant at .001 level
 $F(1,34) = 4.13$ is required for .05 significance
 $F(2,68) = 3.13$ is required for .05 significance

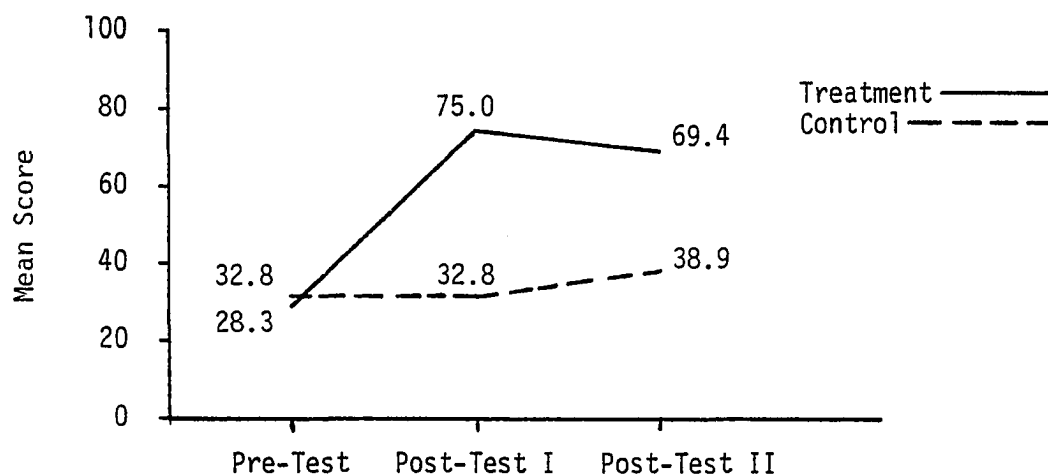


Figure 3

Interaction Between Treatment and Trials for
 Computer Graphics--Subject Matter

This part of the computer graphics test was also administered as a pre-test, post-test I, and post-test II. Table 12 shows the mean score of the treatment and control groups on this survey. Since this was an attitude survey, the higher mean score represents a more positive attitude toward using computer graphics than does a lower mean score. As on previous measurements in this research, the control group had the higher mean score on the pre-test. The greatest change in terms of improvement in attitude for both groups occurred between the pre-test and post-test I. After the pre-test and administration of the treatment of the study, the treatment group had a higher mean score on both post-test I and post-test II than did the control group.

Table 12
Mean Scores for
Computer Graphics--Attitude Survey

| Group | N | Pre- test | std. dev. | N | Post- Test I | std. dev. | N | Post- Test II | std. dev. |
|-----------|----|--------------|--------------|----|-----------------|--------------|----|------------------|--------------|
| Treatment | 18 | 36.79 | 3.28 | 18 | 42.28 | 3.72 | 18 | 43.11 | 3.67 |
| Control | 18 | 37.83 | 4.78 | 18 | 39.56 | 4.60 | 18 | 39.61 | 4.91 |

As with the subject matter portion of the computer graphics test, a 2 x 3 factorial analysis of variance was used to analyze the data for the attitude survey. The summary table of the ANOVA is given in Table 13. The interaction between the treatment and trials was significant at the .01 level, in favor of the treatment group. This interaction is shown graphically in Figure 4. In Figure 4, it can be seen that the control group showed a slight improvement in attitude after the pre-test and kept this same attitude for both the post-test I and post-test II. The treatment group showed more of a change or improvement in attitude than did the control group as indicated by the steeper slope of the treatment line on Figure 4. The treatment group recorded a more positive attitude toward using computer graphics than did the control group after the treatment was administered in this study.

Time per Exercise

To determine the efficiency of the treatment and control groups with respect to use of time, data were collected concerning the time (in minutes) spent on the five exercises drawn by each group. The mean time for the treatment group which used computer graphics was only 5.2 minutes, while the mean time for the control group was 42.0 minutes when similar exercises were drawn manually. A one-way analysis of variance was performed on the data and the results are summarized in Table 14. As shown in the table, there was a significant difference at the .001 level in favor of the treatment group between the

Table 13

Analysis of Variance Summary Table for
Computer Graphics--Attitude Survey

| Source | df | MS | F | p |
|-------------|----|--------|-------|-----------|
| Between | | | | |
| Treatment | 1 | 80.07 | 2.35 | 0.1312 |
| Error | 34 | 34.12 | | |
| Within | | | | |
| Trials | 2 | 178.10 | 18.70 | 0.0000*** |
| Interaction | 2 | 53.46 | 5.61 | 0.0058** |
| Error | 68 | 9.52 | | |

Notes: **significant at .01 level
 ***significant at .001 level
 $F(1,34) = 4.13$ is required for .05 significance
 $F(2,68) = 3.13$ is required for .05 significance

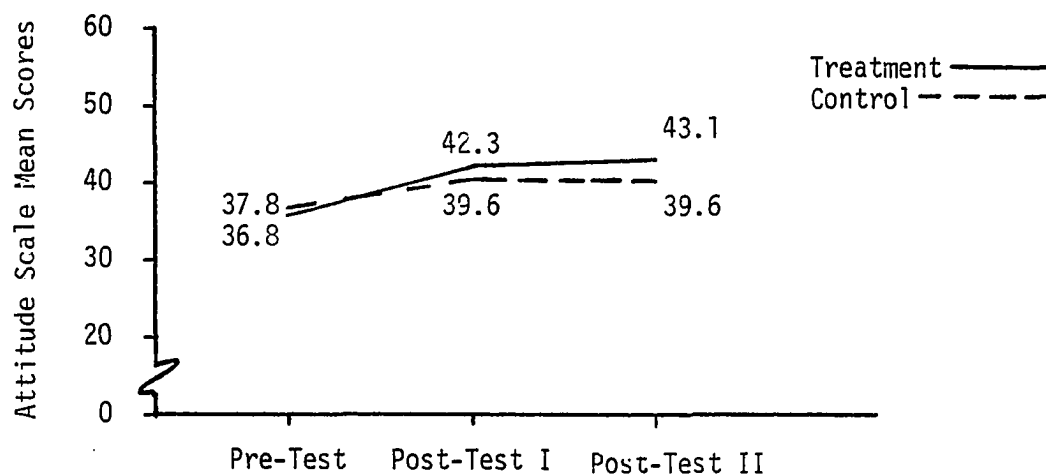


Figure 4

Interaction Between Treatment and Trials for
Computer Graphics--Attitude Survey

Table 14
Analysis of Variance Summary Table for
Minutes per Exercise

| Source | df | MS | F | p |
|-----------|----|-----------|--------|-----------|
| Treatment | 1 | 296555.69 | 344.82 | 0.0000*** |
| Within | 33 | 860.02 | | |

Notes: ***significant at .001 level
 $F(1,33) = 4.14$ is required for .05 significance

treatment and control groups. A difference between the two groups was to be expected due to the labor-saving nature of computers. However, a difference of this magnitude gives even more credit to using this method of teaching engineering graphics.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Educators, in general, and engineering educators, in particular, have recognized that students need to be prepared to use and take advantage of rapidly advancing technologies. One of these rapidly advancing technologies is that of computer graphics which is considered by some engineering educators as a tool rather than a discipline.

Summary

As educators observe the gaining momentum of the industrial use of computer graphics, the need to bring this new technology into the classroom is well recognized. However, because this is a new technology with new problems to consider, many educators are undecided about the best way to incorporate computer graphics into the curriculum so that present students graduating from colleges and universities will be prepared to contribute to and take advantage of this new industrial tool.

Review of Related Literature

The review of literature indicated that engineering educators realize the potential impact of computer graphics in industry and recognize that engineering students need an introduction to

computer graphics. However, the best way to give this introduction has not been established. The introduction needs to come early in the engineering curriculum. Most educators recommended that it should be incorporated into a beginning required course for all engineers, usually in a course taught at the freshman level. In various schools, depending on the arrangement of the curriculum at the school, this beginning required course would usually be Engineering Graphics or Introduction to Engineering.

Many engineering educators considered Engineering Graphics as a logical course in which to introduce computer graphics. Both types of graphics, the traditional manual graphics and the newer technology of computer graphics, could be incorporated into the same course.

While realizing that computer graphics is one more area to integrate into an already crowded course, many engineering graphics educators recognized advantages for combining computer graphics with traditional manual graphics. Computer graphics can be considered a tool in two ways. To the present and future engineers and draftsmen, it is a design and drawing tool. To the engineering graphics educator, it can be considered a teaching tool to enable more graphics material to be effectively taught. Several engineering graphics educators advocated that the basic graphic principles should be taught through traditional manual methods of drawing before students used the computer for the drawings. As often happens, the processes needed to be simplified in the introduction of computer graphics to beginning engineering students. This simplification in computer graphics was made possible through the use of user-oriented computer graphics where

computer programming is minimal. One aspect of computer graphics in which several approaches have been considered is in regard to how much computer programming should be used. Some educators recommend that none should be used, while others suggest combining computer graphics with programming, and still others suggest teaching programming before computer graphics.

After an initial introduction to computer graphics, there were several alternatives to using computer graphics elsewhere in the curriculum. Some educators recommended a required course, sometimes taught at the upper division level, which taught computer graphics as a separate course. Other educators suggested that the computer graphics course should be optional. Some recommended that computer programming should precede the course in computer graphics while other educators suggested that computer programming and computer graphics could be taught together in the same course. Other educators suggested using computer graphics as a tool to apply to different topics in any one of several upper level engineering courses.

Conduct of the Study

After considering the review of literature, this research study was conducted to determine if the use of a combination of manual drawing and computer graphics was an effective way to teach engineering design graphics and to serve as an introduction to computer graphics for beginning engineering students.

A first semester freshman class of Engineering Design Graphics (EDG) 105 students was used as the sample from the population of over

40 sections of EDG 105 during the 1981 fall semester at Texas A&M University. The 38 students from this class were randomly assigned to the treatment and control groups. From the well-established course syllabus, five topics representative of engineering graphics and considered appropriate as introductory material to computer graphics, based on the literature review, were selected. These five topics were bargraph, break-even graph, orthographic projection, isometrics, and obliques. Instruction in these topics was spaced throughout the semester at approximately one topic per week beginning with the third week of the semester. Normally for each new topic introduced throughout the semester, there are several exercises that the students are required to draw. For each separate topic, these exercises progress from simple exercises to more complex (supplementary) exercises.

In this study, the entire class (both treatment and control groups) were introduced to the new topic through a lecture from their professor. Both groups also drew the first exercise on the particular topic through the traditional manual methods of using triangles, drafting machines, and pencils. After the first exercise had been drawn manually by each student in the class, the class was divided into the treatment and control groups to complete the subsequent (supplementary) exercises on the same given topic. These supplementary exercises served to reinforce the same graphic principles that were initially introduced by their professor in the lecture. The control group stayed in the classroom and completed the supplementary exercise using the traditional manual methods involving triangles, drafting machines, and

pencils. At the same time, the treatment group went to the computer room and used computer graphics to draw a similar exercise on the same topic. This sequence was repeated for each of the five selected topics previously mentioned.

In this study, the computer graphics exercises were "user-oriented" and required no programming from the students. The students responded to questions appearing on the computer screen (CRT) regarding different aspects of how the student wanted the drawing constructed. An assistant (a qualified EDG professor) was in the computer room to give assistance if needed.

Data Collection

To determine the outcomes of the research, measurements were taken on three primary factors to determine if there was a significant difference between the treatment and control groups at the .05 level of significance. These measurements were weekly quizzes, comprehensive examination (used as a pre-test and post-test), and a computer graphics test (given as a pre-test, post-test I, and post-test II). Two of these, the weekly quizzes and comprehensive examination, were routinely administered to all students in the EDG department. The weekly quizzes were prepared by qualified professors for departmental use, and the comprehensive examination had been in use for several years in the department. The computer graphics test was prepared especially for this research. It was composed of two parts, with the first part being concerned with basic knowledge regarding computer graphics. Although the goal of this study was not

to teach computer graphics per se, but rather to use computer graphics as a tool to teach engineering graphics subject matter, the purpose of the computer graphics test was to determine if the students had additionally learned some basic information regarding computer graphics. The second part of the computer graphics test was an attitude survey to determine how interested the students would be in using computer graphics. A fourth measurement was taken regarding how much time (in minutes) the students spent in completing the exercises of this study. The purpose of measuring time was to determine the efficiency of the two methods.

Findings

The procedure used to analyze the data in all cases was analysis of variance. From the data analysis, it appeared that there were no significant differences between the computer graphics (treatment) and manual (control) groups on the five weekly quizzes. On the comprehensive examination, analysis of variance revealed an interaction which was significant at the .01 level when all questions on the exam were used and significant at the .05 level when the questions unrelated to this study were deleted and only the pertinent questions were used. On the computer graphics subject matter test, the interaction between the treatment (computer graphics and manual groups) and the trials (pre-test, post-test I, and post-test II) was significant at the .001 level of significance. The computer graphics attitude survey showed a significant interaction at the .01 level between the same treatment (computer graphics and manual groups) and trials (pre-test, post-test I,

and post-test II). Analysis of time per exercise revealed a significant difference at the .001 level between the treatment and control groups. The mean time per exercise with the computer graphics was only 5.2 minutes while the mean time per similar exercise with the manual group was 42.0 minutes.

An observation of interest that occurred during the study was the inquisitiveness (or lack of inquisitiveness) exhibited by the students in regard to experimenting with computer graphics. In industry, one of the advantages of using computer graphics is that minor routine modifications of designs are made very easily and quickly through the use of interactive computer graphics. When the students in the computer graphics (treatment) group had completed their assignment successfully, and often this was done within a very few minutes, there was little or no interest in trying the problem another way. The students were not encouraged to try the problem again, but neither were they discouraged nor prevented from making such attempts. Perhaps the reason was that once the students had completed their assignment, they moved on to another task. Another reason might have been that the students knew they were required to tell how many minutes they spent on the exercises, and this in some way reduced their desire or freedom to experiment. Similarly, the students in the control (manual) group expressed little interest in using the computer graphics equipment after the research study was completed. Perhaps timing was the major factor. The time during the semester when the control group was allowed to use the computer graphics facilities was during the week when they were preparing for final examinations in their other courses.

Conclusions

The results indicated that first semester freshman engineering graphics students who were taught engineering graphics through a combination of traditional manual exercises followed by user-oriented computer graphics which did not include any computer programming benefited more in several ways than did the students who were taught engineering graphics using only the traditional manual methods. The findings resulting from the data analysis form the basis for the following conclusions:

1. On the five weekly quizzes which covered the portion of the semester in which this research was conducted, the mean percent score of the group which received the treatment of using computer graphics was slightly higher than the mean percent score of the control group which used only the traditional manual methods of graphics. Based on analysis of variance, this was not statistically significant; and, it may be concluded that the treatment had no significant short-term effect on the learning of engineering graphics principles by either the treatment or control groups.

2. The results and analysis of the data for the comprehensive examination did show a significant interaction in favor of the treatment group between the treatment (computer graphics and manual groups) and the trials (pre-test and post-test). It may be concluded, therefore, that the application of the treatment favorably affected the overall retention of engineering graphic principles by the students who did receive the treatment.

3. The results and analysis of the data from the computer graphics test also showed a significant interaction between the treatment and trials in favor of the group receiving the treatment. Here again, as with the comprehensive examination, it may be concluded that the application of the treatment caused the students who received the treatment to learn more of the basic principles of computer graphics than did the students who did not receive the treatment. This was as hoped and expected, because the treatment group had learned some computer graphics at the same time they were learning engineering graphics.

There was a more pronounced difference between the treatment and control groups on post-test I immediately following the application of the treatment than on post-test II which was delayed until later in the semester to measure long-term retention. Thus, the favorable effects of the treatment tended to be more effective for a shorter time span than for a longer time span. As expected, since they were not directly exposed to computer graphics, the control group showed no gain in knowledge of computer graphics principles between the pre-test and post-test I. However, unexpectedly, the mean score of the control group on post-test II showed a slight, though apparently insignificant, gain over the previous two administrations of the computer graphics test. The control group did increase their knowledge of computer graphics slightly although they did so through indirect means. Although there is no direct evidence, there might have been some contamination between the treatment and control

groups after the completion of the treatment application. Possibly the control group benefited from being part of the study also, and they managed to increase their knowledge of computer graphics because of their association with the treatment group.

4. The attitude survey regarding using computer graphics showed a significant interaction in favor of the treatment group between the treatment and trials. In contrast to the computer graphics subject matter test, the treatment group continued to show an improvement in attitude over the time span from post-test I to post-test II. Therefore, it may be concluded that the application of the treatment caused the students who received the treatment to improve their attitude toward the use of computer graphics.

5. The treatment group which used computer graphics needed far less time to complete the five exercises in this study than did the control group which used only the traditional manual methods for drawing similar exercises. Therefore, it may be concluded that in terms of time required by the students to complete related exercises, the treatment was a much more efficient method to teach engineering graphics. Since computers are well known for the speed with which they can operate, this was not a surprising result.

6. The students who used a combination of computer graphics and traditional manual drawing (treatment group) obtained quiz and examination scores which were higher than those of the students who used only the traditional manual methods of drawing (control group). The data analysis indicated that the treatment resulted in no

practical difference in the two group's achievement on weekly short-term quizzes regarding engineering graphics, but there was a favorable difference for the treatment group regarding long-term retention of engineering graphic principles. As expected, the treatment group additionally showed a significantly higher gain in their knowledge of computer graphic basic principles. The treatment group accomplished the task of learning engineering graphics as well or better than the control group while also learning much more about computer graphics. At the same time, the treatment group required significantly less time to learn the principles being taught. It may be concluded, therefore, that the method of teaching engineering graphics through a combination of traditional manual exercises followed by user-oriented computer graphics (without any programming) is an efficient and effective way to teach engineering graphics and simultaneously introduce computer graphics to the freshman engineering student.

Recommendations

Based on the findings and conclusions of this research, the following recommendations are made:

1. It is recommended that this method of teaching first-semester freshman engineering graphics principles through a combination of manual drawing followed by interactive computer graphics be implemented as soon as possible into first-semester engineering graphics courses in colleges and universities which have interactive computer graphic facilities. Additional areas of course content

could also be included with the program because of the time saved in solving supplementary problems.

2. It is further recommended that this method of teaching first semester freshman engineering graphics principles through a combination of manual drawing followed by interactive computer graphics be tried by institutions of higher learning for the purpose of educational verification.

3. A more specific recommendation is that colleges and universities which are presently teaching traditional engineering graphics and using other methods to introduce and/or teach computer graphics include the previously described method to introduce computer graphics during the first semester engineering graphics course. This approach may serve as a motivator to bring more students into advanced computer graphics courses.

4. When reassessment of curricula and/or facilities is made for the purpose of upgrading educational endeavors in teaching engineering graphics, it is recommended that considerations be made to facilitate the teaching of first semester freshman engineering graphics through this method of a combination of manual drawing followed by interactive computer graphics.

5. As with any program involving sophisticated equipment, it is recommended that the computer graphics facilities be properly maintained and that qualified service personnel be readily available to give assistance as needed.

6. Because there is rising interest in introducing computer graphics into the engineering curricula throughout the country, it is recommended that a better way be devised for pooling and sharing knowledge of computer graphics educational software among interested institutions with related needs. Journal articles and conference meetings are helpful to some extent but are often not helpful enough. Perhaps a regularly updated extensive compilation and listing of institutions with data regarding software and related items could be made available to interested institutions and individuals.

7. An additional recommendation would be to conduct a follow-up study on the students who were participants in this research to determine if there were lasting long-term effects regarding interest in using computer graphics and retention of basic computer graphics facts.

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APPENDIX A

Computer Graphics Test

Please place all responses on the red answer sheet provided. Use a number 2 pencil (F or HB lead). Fill in your name and shade in the appropriate "bubble" for each letter. In a similar manner, shade in the letter of the appropriate "bubble" for your responses to the questions. Be sure that you give only one response for each question. Please answer all questions.

1. When drawing on the computer, the pen must be in what position to actually draw a line? A. up, B. down, C. top of screen, D. to the right of the screen.
2. To skip a space on the screen, the pen must be in what position? A. up, B. down, C. bottom of screen, D. to the left of the screen.
3. If a paper copy of the drawing on the screen is desired, this is done A. in the computer center in another building on campus, B. on the printer, C. on the plotter, D. through a special photographic process in the terminal.
4. If a scale factor less than 1.0 is chosen for a drawing in computer graphics, which of the following is NOT true? A. The results might be too large for the screen, B. The results might be too small to be easily interpreted, C. The drawing will be less than full size, D. The drawing will usually be less than 1 inch tall.
5. A data file is used: A. to store the coordinates of a drawing, B. to store only the pen values of a drawing, C. to store coordinates and pen values for a drawing, D. to store the responses students give to plates.
6. When a drawing is made in computer graphics A. the drawing always begins in the upper left corner of the screen, B. all horizontal lines are drawn first, C. all vertical lines are drawn first, D. The drawing is made up of a series of segments that moves about the screen as one continuously moving line.
7. When making a drawing in computer graphics, A. there are several possible correct combinations of the data involved, B. there is only one best combination of the data involved, C. the computer will decide which of several solutions is best, D. the student can override the computers selection of the one best solution.
8. Typographical mistakes on the same line may be corrected by A. pressing the 'Control' key and 'C' key simultaneously, B. pressing the 'Control' key and 'H' key simultaneously, C. pressing the 'Delete' key D. only by starting the program again.
9. To start a drawing in computer graphics, the student selects from a group of programs available called: A. a menu, B. an agenda, C. a key, D. a shelf.
10. When making a drawing with the computer the drawing A. will automatically be centered on the screen by the computer, B. might be too large for the screen, C. will always start on the right half of the screen, D. will automatically be enlarged or reduced by the computer.

On the answer sheet, mark the appropriate "bubble" for one response for each statement (11 - 20). Respond by indicating where your personal opinion would fall on a scale ranging from: A = strongly agree to, E = strongly disagree. Please give a response to all statements.

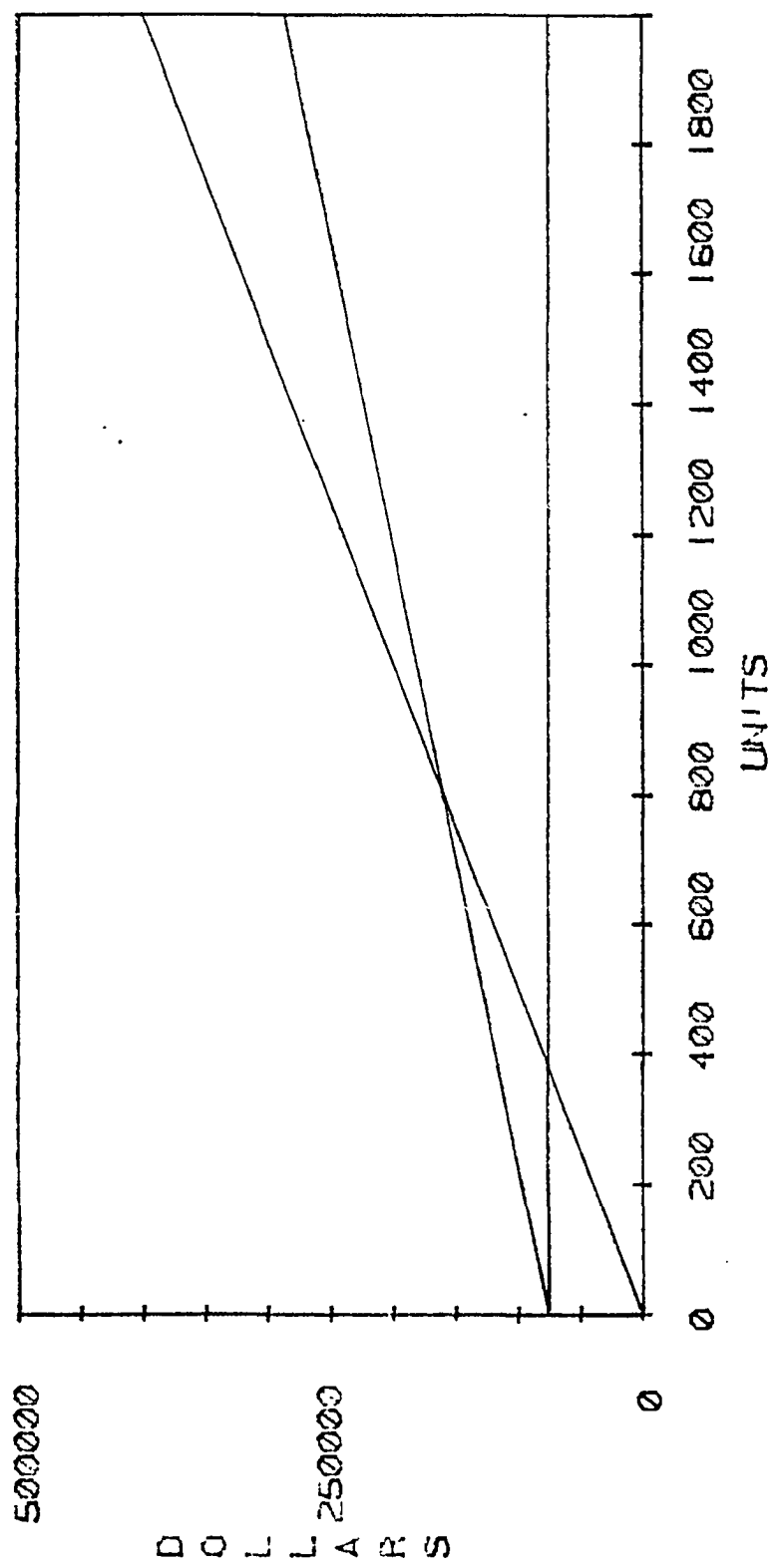
A = strongly agree
B = agree
C = neutral, no opinion, don't know
D = disagree
E = strongly disagree

11. Computer graphics saves time when modifying drawings.
12. Computer graphics can be used easily for numerous modifications to existing designs.
13. Computer graphics is more useful in latter design phases than it is in the initial drawing.
14. Computer graphics can be used to obtain numerical and analytical data as well as drawings.
15. Before a person can use computer graphics, he should first know some of the basics about how a drawing would be made manually.
16. After graduation, I would like to work for a company where I could use computer graphics myself.
17. After graduation, I would like to work for a company where computer graphics was available for others to use.
18. Using computer graphics helps the student visualize two-dimensional drawings.
19. Using computer graphics helps the student visualize three-dimensional drawings.
20. Computer graphics can be beneficial to students in solving engineering graphics exercises.

APPENDIX B

Treatment Group (computer graphics) Assignments

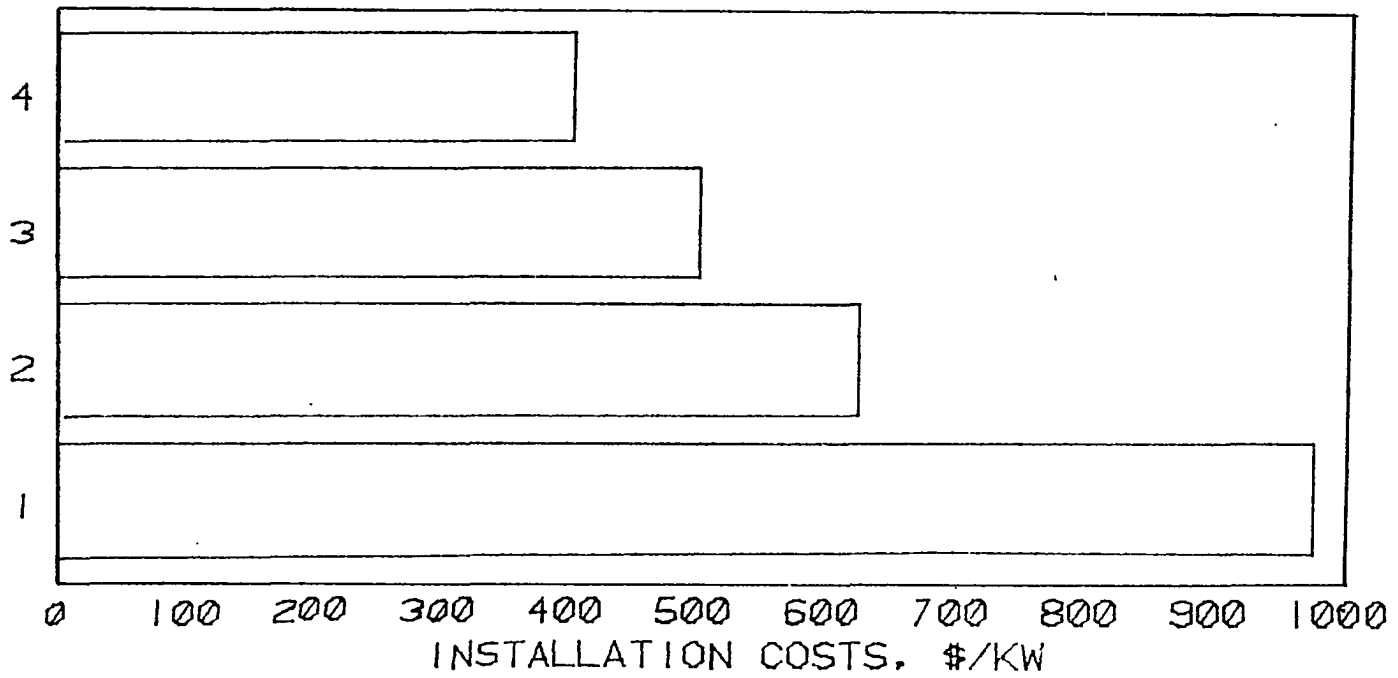
BREAD-EVEN GRAPH FOR SOL...



Bar Graph

Note: Lettering flaws are due to technical hardware problems.

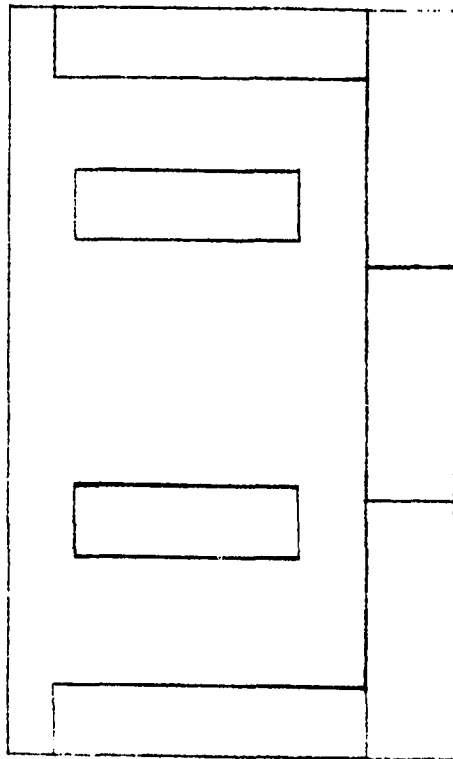
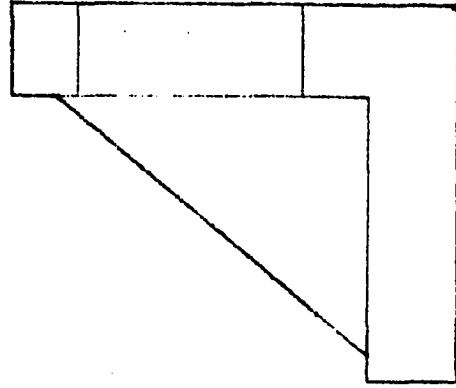
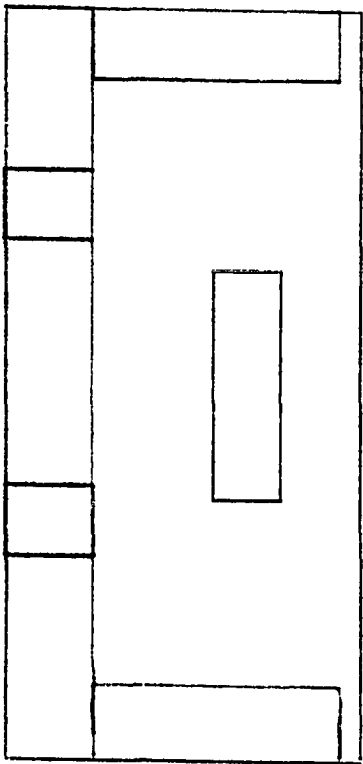
ESTIMATED COSTS FOR ELECTRIC P



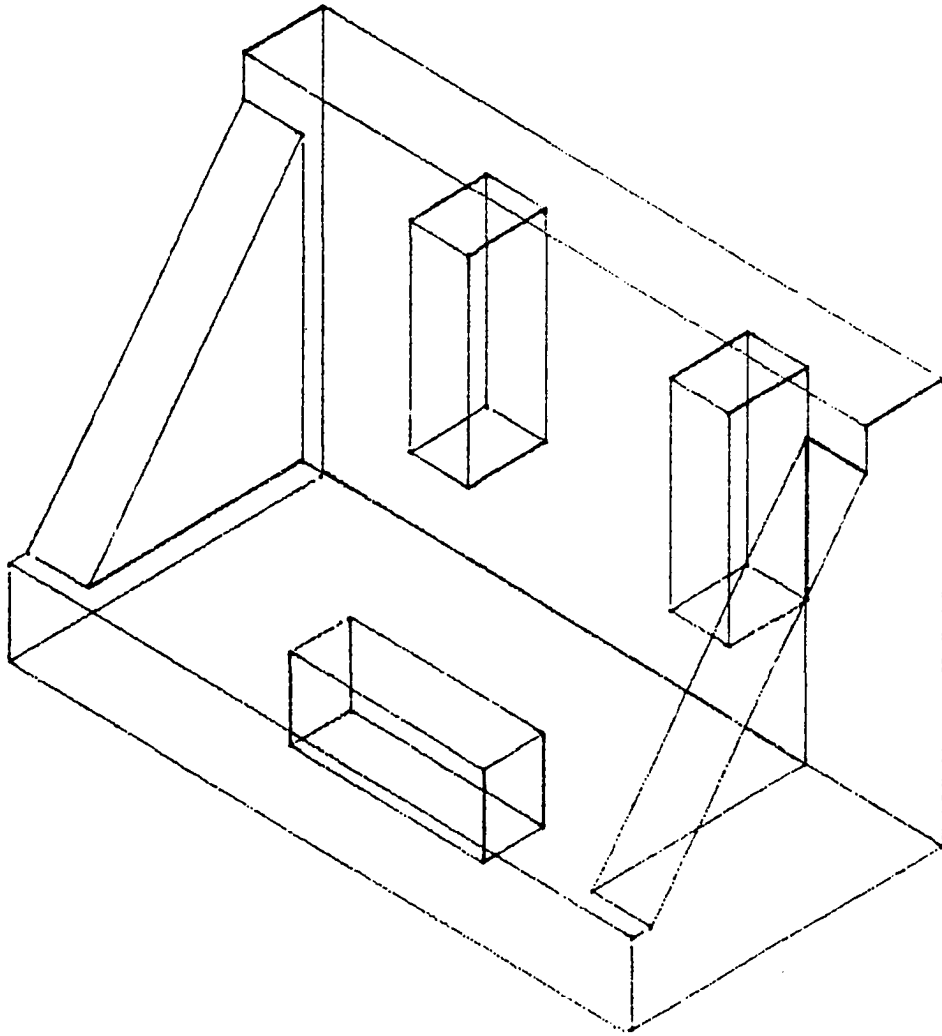
- 1. IS FOR NUCLEAR.
- 2. IS FOR WIND.
- 3. IS FOR GEOTHERMAL.
- 4. IS FOR COAL.

Breakeven Graph

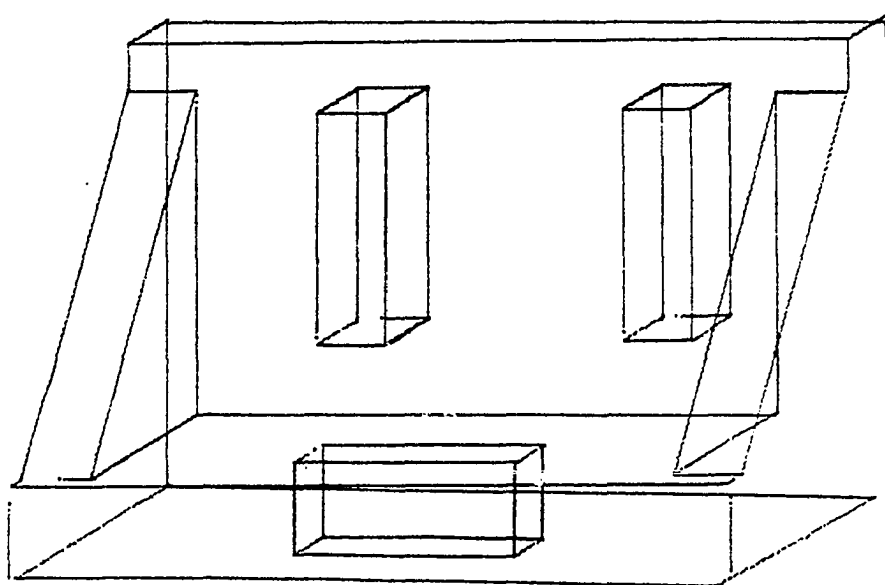
Note: Lettering flaws are due to technical hardware problems.



Orthographic Projection



Isometric Drawing



Oblique Drawing

APPENDIX C**Control Group (manual)****Assignments**

Graphs For Engineers
 NAME: _____
 FILE: _____
 SEC: _____
 DATE: _____
 MIN. GRADE: **30**

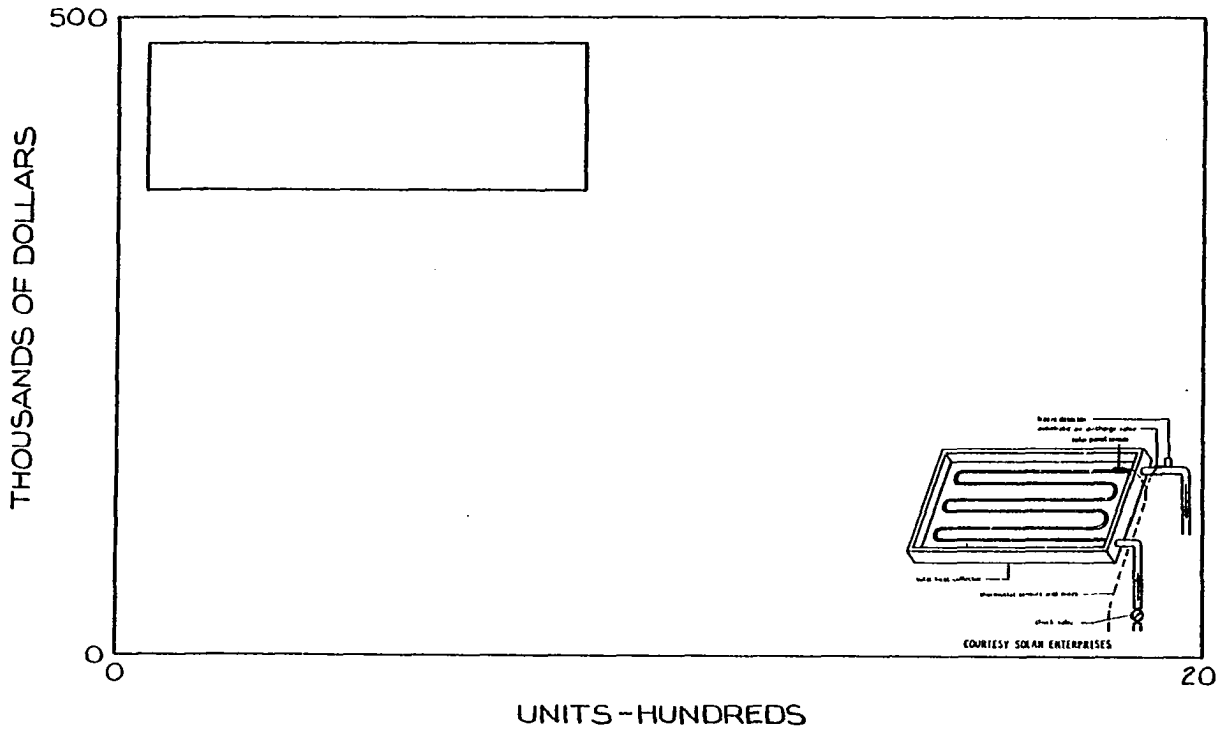
GRAPHS

AN ALUMINUM COMPANY THAT MANUFACTURES SOLAR COLLECTORS SPENT \$50,000 ON RESEARCH AND DEVELOPMENT AND \$26,000 TO SET UP A COLLECTOR ASSEMBLY LINE. THE MANUFACTURING COSTS PER UNIT ARE SHOWN IN THE TABLE. PLOT THE DATA, LABEL THE AXES, AND PROVIDE A TITLE FOR THE GRAPH. DETERMINE THE NUMBER OF COLLECTORS THAT MUST BE SOLD IN ORDER TO BREAK EVEN IF THE COLLECTORS ARE SOLD FOR \$260 EACH.

SOLAR COLLECTOR MANUFACTURING COSTS PER UNIT

| ITEM | COST |
|--------------|--------------|
| MATERIAL | \$ 40 |
| LABOR | 34 |
| OVERHEAD | 31 |
| TOTAL | \$105 |

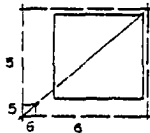
1. IF THE COLLECTORS ARE SOLD FOR \$200 EACH, HOW MANY MUST THEY SELL IN ORDER TO BREAK EVEN?
2. WHAT IS THE COST PER UNIT IF 1000 UNITS ARE SOLD?
3. WHAT WILL BE THE PROFIT IF 1600 UNITS ARE SOLD?
4. WHAT WILL BE THE LOSS IF THEY BUILD AND SELL ONLY 400 UNITS?
5. WHAT WILL BE THE TOTAL PROFIT IF THEY SELL ALL 2000 UNITS?



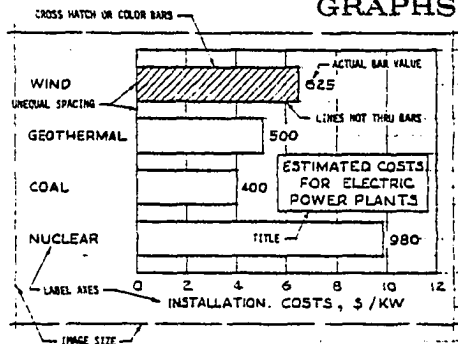
GRAPHS

IN A RECENT YEAR A PUBLIC UTILITY CALCULATED THE COST PER KILOWATT - HOUR FOR THE CONSTRUCTION OF SEVERAL DIFFERENT TYPES OF ELECTRIC GENERATING FACILITIES. THE DATA ARE SHOWN IN THE GRAPH AT THE RIGHT AND IN THE TABLE BELOW. WITH INSTRUMENTS DRAW AN ENLARGED BAR GRAPH IN THE SPACE BELOW. THE IMAGE SIZE SHOULD BE IN 5:6 PROPORTIONS FOR A FIGURE IN A REPORT. RANK THE BARS SO THAT THE SMALLEST IS AT THE TOP AND THE LARGEST IS AT THE BOTTOM.

| FUEL TYPE | INSTALLATION COST (DOLLARS / KW) |
|------------|----------------------------------|
| COAL | \$ 400 |
| NUCLEAR | 980 |
| GEOTHERMAL | 500 |
| WIND | 625 |



GRAPHS



JTB

| | | | | |
|-------------------------------|---------|------|-------|-----------|
| Graphics for Engineers | NAME: | MIN. | GRADE | 31 |
| | © FILE: | SEC: | DATE: | |

THE ANGLE BRACKET SHOWN HERE IS TO BE MODIFIED IN ACCORDANCE WITH THE FOLLOWING SPECIFICATIONS:

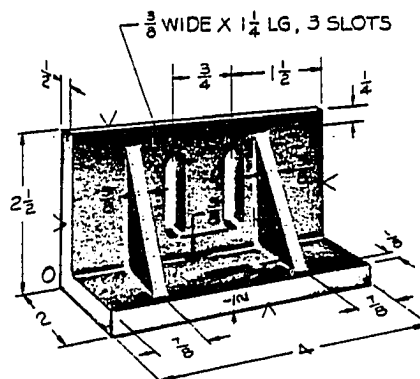
MOVE THE TWO RIBS TO THE OUTSIDE ENDS OF THE ANGLE.

CENTER THE TWO VERTICAL SLOTS ABOUT THE CENTER OF THE UPRIGHT ANGLE AND SPACE THEM 1-1/2" APART.

DESIGN THE SLOTS TO BE RECTANGULAR

CONSTRUCT THREE ORTHOGRAPHIC VIEWS OF THIS FULL-SIZE PART, EITHER WITH INSTRUMENTS OR FREEHAND AS ASSIGNED.

ORTHOGRAPHICS



| | | | | |
|-------------------------------|------------------|------|-------|-----------|
| Graphics for Engineers | NAME: | MIN. | GRADE | 36 |
| | FILE: SEC: DATE: | | | |

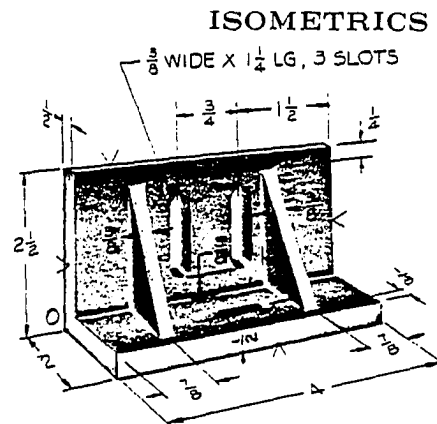
THE ANGLE BRACKET SHOWN HERE IS TO BE MODIFIED
IN ACCORDANCE WITH THE FOLLOWING SPECIFICATIONS:

MOVE THE TWO RIBS TO THE OUTSIDE ENDS OF
THE ANGLE.

CENTER THE TWO VERTICAL SLOTS ABOUT THE CENTER
OF THE UPRIGHT ANGLE AND SPACE THEM 1-1/2" APART.

DESIGN THE SLOTS TO BE RECTANGULAR

CONSTRUCT A FULL SCALE ISOMETRIC DRAWING
OF THE MODIFIED BRACKET



ok

| | | | | |
|-------------------------------------|------|------|-------|----|
| Graphics for Engineers © | NAME | MIN. | GRADE | 41 |
| | FILE | SEC. | DATE | |

THE ANGLE BRACKET SHOWN HERE IS TO BE MODIFIED
IN ACCORDANCE WITH THE FOLLOWING SPECIFICATIONS:

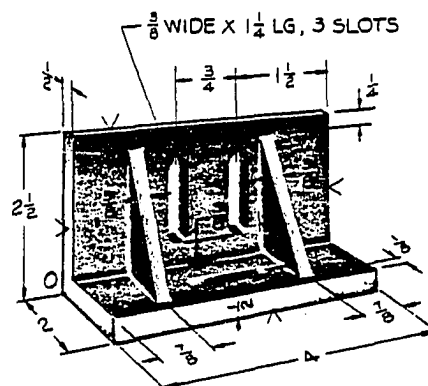
MOVE THE TWO RIBS TO THE OUTSIDE ENDS OF
THE ANGLE.

CENTER THE TWO VERTICAL SLOTS ABOUT THE CENTER
OF THE UPRIGHT ANGLE AND SPACE THEM 1-1/2" APART.

DESIGN THE SLOTS TO BE RECTANGULAR

CONSTRUCT A FULL SIZE CAVALIER OBLIQUE DRAWING
OF THE MODIFIED BRACKET

OBLIQUES



OK

| | | | | |
|-------------------------------------|------------------|------|-------|----|
| Graphics for Engineers © | NAME: | MIN. | GRADE | 45 |
| | FILE: SEC: DATE: | | | |

VITA

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The typist for this dissertation was Linda Stewart.