A STUDY TO DETERMINE IF BEGINNING ENGINEERING DESIGN AND DRAFTING STUDENTS SHOULD LEARN VISUALIZATION SKILLS USING THREE DIMENSIONAL COMPUTER GRAPHICS

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A STUDY TO DETERMINE IF BEGINNING ENGINEERING DESIGN AND DRAFTING STUDENTS SHOULD LEARN VISUALIZATION SKILLS USING THREE DIMENSIONAL COMPUTER GRAPHICS

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

PREFACE

This study was addressed to determine if three dimensional computer graphics should be used at the college and university level to teach visualization skills to beginning engineering design and drafting students. A goal of the study was to determine the pedagogical opinion of current Oklahoma college and university engineering graphics instructors concerning the use of 3D computer graphics as a beginning teaching tool. To accomplish this goal, a survey was mailed to each instructor currently teaching engineering graphics in Oklahoma. I am exceedingly grateful to all of the instructors who returned the survey. Without their cooperation and valuable input, this study would not have been possible.

I would also like to express my appreciation to Dr. Gary Oakley, Dr. Robert Nolan and Dr. Ray Sanders of the School of Occupational and Adult Education at Oklahoma State University for their time and advisement during this study.

The faculty and staff of the Technology Department at Cameron University have been very supportive throughout the process of this research. I express my sincere gratitude to them and to especially Mr. Tom Sutherlin who has been very helpful and knowledgeable throughout this study and throughout my career.

To my wife, Kacey, I am extremely appreciative. Her support and encouragement has made this study and my goals possible.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Background

Engineering design and drafting students are taught how to visualize three dimensional objects using a two dimensional technique called "orthographic projection". Visualization is the process of mentally comprehending visual information (Bertoline, 1993). It is a skill that is usually taught, among many others, to beginning engineering design and drafting students during the first semester of a student's freshman year in both two-year and four-year programs. Visualization skills are necessary components of any engineering design and drafting curriculum and profession. The concept of teaching visualization has been standard over the years, based on old and proven techniques. While these techniques do work, the technology now exists that could allow a student to better visualize three dimensional objects on a computer monitor using three dimensional computer graphics software.

Spatial visualization skills are important to engineering design because of their direct relationship to graphical communication (Devon, 1994). A student who cannot develop these skills will be severely limited in any profession involving the design and manipulation of three dimensional objects. Many design students possess visualization skills long before they are formally taught the concept. Existing research suggests that visualization is a psychological skill that is not possessed by all people. The research also implies that even if a person does possess three-dimensional visualization skills, these skills may still need to be refined in order for them to be used (Devon,1994). The responsibility then of refining and developing these required skills is that of the college or university engineering design instructors.

The Problem

Engineering design disciplines require that students know how to mentally visualize three dimensional objects. The teaching of visualization is a very difficult task. How do students learn to visualize objects? What is the best method for teaching beginning engineering design students to visualize? Currently, visualization skills are taught using two-dimensional "flat" techniques. While visualization can generally be learned with these techniques, some students still have difficulty mastering this important engineering communication skill (Kashef, 1991).

Because of the now available computer hardware and three-dimensional software, alternative techniques for teaching visualization skills are feasible. The use of three-dimensional computer graphics could allow for more advanced and faster learning of visualization skills. These techniques could allow for the learning of more subject matter in less time (Bertoline, 1991).

The problem with which this study is concerned is whether or not the current technology of three-dimensional computer graphics should be used to teach visualization as compared to the "old" technique of two-dimensional orthographic projection. The concept of visualization is based on three-dimensional concepts. Students should not be learning three-dimensional theories with two-dimensional tools. Furthermore, the way two-dimensional methodology is used to teach visualization has very little to do with most situations in industry (Bowers, 1993).

Until now, students were limited to learning these concepts with two-dimensional techniques. Because the use and importance of two-dimensional graphics techniques as compared to three-dimensional techniques is declining, alternate methods of curriculum delivery is needed (Bertoline, 1993), The era of using two-dimensional techniques to teach visualization has ended with the application of three-dimensional computing technology (Bertoline, 1991).

Purpose of the Study

The purpose of this study was to determine if college and university instructors believe that beginning engineering design and drafting students at an entry level should learn visualization skills using three-dimensional computer graphics rather than using two-dimensional computer graphics and orthographic projection. This research sought to determine if sufficient data existed to conclude that three-dimensional computer graphics should or should not be used to teach visualization at an entry level. Also, this research sought to determine the relative importance of engineering design graphics curriculum content in Oklahoma colleges and universities. An additional purpose of this study was to determine if Oklahoma engineering design graphics instructors used three-dimensional computer graphics in their freshman level design courses. If three-dimensional graphics were being used, the research sought to determine how and to what extent.

Objectives of the Study

The objectives of this study were as follows:

1. To determine if professional Oklahoma educators in the field of engineering design graphics used three-dimensional computer graphics in their entry level courses.
2. To determine if current research in the field of engineering design

graphics supported the idea of using three-dimensional computer graphics to teach entry level visualization skills.

3. To establish justification for developing alternative curriculum delivery methods for the teaching of visualization skills at a higher education level.

Significance of the Study

The significance of this study is that alternate means of course content delivery could be established to facilitate the learning of visualization skills at a beginning level. An alternative method of teaching visualization skills could be determined based on computer technology. If so, students could learn visualization faster and more efficiently, thus better serving and preparing the student. Course content could be improved to allow beginning students to learn visualization at an advanced level. If students could learn visualization at an accelerated pace, more time could be spent concentrating on other engineering design concepts. Industry demands better prepared employees. If more concepts could be covered in less time, industry would get better prepared entry level employees.

It is important that engineering design students understand the concept of visualization at an early learning stage because advanced courses require visualization as a learning prerequisite. Creating technical drawings and designs in industry requires visualization skills (Kashef, 1991). It is also important for students and faculty to understand that the use and knowledge of new engineering tools such as three-dimensional computer graphics is demanded by industry as well. Industry is currently using three-dimensional techniques as a predominate design tool. In order for college and university engineering and engineering design programs to do its job correctly, they must provide what industry needs.

Assumptions

To facilitate the objectives of this study and to focus on computer assisted curriculum only, the study was based on the following research assumptions.

1. College and university engineering and engineering design students have access to three-dimensional computer graphics hardware and software.
2. Two-dimensional computer graphics software is currently used to teach engineering design graphics to college and university design students.

Scope and Limitations

1. Only data from public college and university programs in Oklahoma were used in the compiled results.
2. Institutions included in the results of this study could not have been using traditional (manual) engineering design graphics methods exclusively.

Definition of Terms

Computer Graphics - The graphical output of analytical data which has been processed by a digital computer (Sutherlin, 1975).

Computer-aided Drafting (CAD): - The process of creating a drawing using computer hardware and software (Nwoke, 1993).

Entry Level Student - A beginning (freshman) college or university student with no experience in computer graphics or drafting principles.

Industry - Any potential employer of Engineering Design and Drafting graduates including industrial firms, government agencies, and businesses (Sutherlin, 1975).

Mental Rotation Test - A test developed by Vandenberg and Kuse in 1978, used as a measure of spatial visualization skills (Devon, 1994).

Orthographic Projection - The process of representing three dimensional objects by separate, two dimensional views arranged in a standard manner on a two dimensional medium (Earle, 1994).

Solids Modeling - The process of creating computer generated, three dimensional objects that are completely and unambiguously defined such that they not only have edges and surfaces, but the surfaces completely enclose one or more volumes.

Space Geometry: - The science of graphic representation by which objects are manipulated in 3D space on computers for the purpose of solving problems related to them (Bertoline, 1991).

Three dimensional (3D): - The property of an object in space having the three physical proportions of length, depth and height.

Traditional Drafting (TRAD): (Also called Manual Drafting) - The process of creating a drawing on paper using pencil and paper and such drawing tools as a drawing board, T-square, drafting machine and triangles (Nwoke, 1993).

Two Dimensional (2D) - The property of a view of an object having the two physical proportions of length and height.

Visualization: - The process of mentally comprehending visual information (Bertoline, 1993).

Visualization Skills - The processes or skills necessary to mentally manipulate an object in three dimensional space to acquire a different view of the object.

CHAPTER II

REVIEW OF THE LITERATURE

Computer Graphics Background

Computers and computer graphics have been used in mechanical design and engineering disciplines since the early 1960's (Kopf, 1992). Industry has evolved from using traditional drafting (two-dimensional layout on a drawing board) to using computer graphics as its primary design tool. Because of industry's change in design tools, engineering design curriculums in colleges and universities have had to change to meet new needs.

Over the past thirty years, computer hardware and software technology has advanced to a level that allows for very high level computing at a relatively low price. Both industry and education have recognized these advances and lowering costs and are now finding more applications for three-dimensional computer modeling (Bertoline, 1993). Industry demands faster and more efficient hardware and software to gain superiority over competitors. To meet the demanding needs of industry, engineering design curricula at the higher education level have had to adopt the use of computers as a necessary design tool. The principal way that computers have been integrated into higher education and engineering design curricula is through the use of computer graphics, and specifically the use of two-dimensional Computer Aided Drafting (CAD).

In engineering design, computer graphics are used in two distinct ways. The oldest and most common way of use is the traditional, two-dimensional approach. The two-dimensional applications of computer graphics are those that developed from the traditional, or manual, drafting and design techniques. These techniques have been modified over the years but have not been abandoned (Bertoline, 1991). Two-dimensional computer graphics techniques were a major advancement in the way engineering drawings were produced due to increased drawing generation speed and increased drawing accuracy. It is now possible, however, to be even more accurate and faster by solving graphical problems using computers and three-dimensional software (1991).

Three-dimensional implies that the drafter or designer uses computer graphics to view an object on a computer monitor as the object would appear in reality. The use of three-dimensional graphics has been limited in the past due to the massive computing power needed to represent a true three-dimensional image on a computer monitor. The advancements made in computing technology have made three-dimensional image processing easier and cost efficient.

Visualization

Both the two-dimensional and the three-dimensional approach to engineering design are established in industry and in education. Engineering design instructors are now confronted with the issue of which approach is best for students to learn the important concepts of graphical communication. One of the most important and fundamental concepts presented to beginning engineering design students is "visualization".

Visualization skills are fundamental to those professionals (engineers, drafters, technologists...) involved in the design of any manufactured product. The ability to think and visualize in three dimensions is one of the most important and essential skills necessary to professional engineering designers (Kashef, 1991). Visualization leads to new knowledge and better understanding of a product under development (Bowers, 1993). These skills allow a designer to mentally manipulate three dimensional geometry to obtain different views of an object. Being able to build a three-dimensional model in one's mind is a necessary design tool. This design tool, to most students, is one which must to learned through practice and patience (Bolluyt, 1993).

How a beginning student should learn these skills is the subject of this study. Should three dimensional computer graphics be used to teach beginning engineering design and drafting students the essential visualization skills needed for success in engineering design professions or should traditional, two dimensional techniques be used.

Beginning engineering design students were taught to visualize using two-dimensional computer and two-dimensional manual (hand drawn) graphics. These techniques were and are the same ones used for teaching visualization with "manual" drafting instruments. While these methods were adequate for their time, a more direct approach to visualizing three dimensional objects using current computer graphics technology is needed. Improving the visualization skills of students is one of the primary objectives of modern engineering design graphics curriculums (Agrawal, 1987). This was true when traditional drafting methods were taught and when computer graphics were introduced into design engineering. This priority placed on learning visualization has not changed. The only apparent change in the way the concepts are currently being taught is the medium.

The problem with the current way of teaching three-dimensional visualization is that instructors are teaching this concept using two-dimensional techniques and mediums. Students are being taught how to think in three dimensions while using a two-dimensional system (Bolluyt, 1993). Now that three-dimensional techniques are known and the technology is available at reasonable costs, this problem can be examined.

The use of three-dimensional graphics is possibly the most important aspect of computer graphics (Watt, 1989). Although three-dimensional computer graphics have existed since the late 1960s, the use of 3D has been restricted due to hardware and software limitations (Kopf, 1992). These limitations have caused computer graphics to be used primarily as a two-dimensional design tool.

Industry and Education

The use of computers in the engineering design process has made a major impact in industry and in higher education. Because of the extensive use of computer graphics in industry, engineering and design education are faced with the challenge of preparing students to have the knowledge and skills necessary to meet the design and drafting needs of industry (Nwoke, 1993). Computers enhance the students's comprehension of the design process, thus enabling the student to become better industrial employees (Anand, 1993). The trend in industry is for designers to be proficient in computers and in three-dimensional geometric modeling (Bertoline, 1993). Industry's use of computer technology in such areas as computer-aided design and computer-aided manufacturing has changed the execution of engineering principles. Due to these changes, colleges and universities have had to change their programs to meet industry's needs (1993).

In recent years, three-dimensional software and hardware has advanced to a level suitable for use on micro-computers. These advancements have allowed not only industry to use three-dimensional computer graphics, but they have also made it possible for colleges and universities to use the tool as well. While large capability computer graphics systems still cost too much for most engineering schools, small systems that offer lower graphics capabilities are feasible (Barr, 1984).

The use of three-dimensional methods should allow a student to better understand the spatial relationship of different views of an object, and at the same time prepare the student to use a tool that has been adopted in many industrial design fields. Zsombor (1990) suggested that visualization should be taught using a combination of two-dimensional and three-dimensional methods. He argued that three-dimensional techniques alone were not enough and that two-dimensional methods should be used in conjunction with three-dimensional methods. Industry is still using two-dimensional computer graphics, so Zsombor suggestion has practical significance.

Although the debate continues between engineering design educators on whether students can think and visualize more critically with computer graphics than with traditional (manual) graphics (Kashef, 1991), it should be noted that the computer is a "tool". It is a tool that both industry and higher education alike have adopted. If engineering design students are to be prepared at the end of a two-year or a four-year program, they must be informed about these tools and the latest engineering processes available (Anand, 1993). The new uses of engineering tools are now allowing students real industrial experiences in pre-industrial settings. This would not have been possible without the use of three-dimensional computer graphics (Kashef, 1991).

Current Research

Although higher education has adopted the use of computer graphics, little research could be found to support what method of delivery is best for teaching college and university level visualization skills. Most of the cited sources in this study implied that three-dimensional techniques should be used. Only one qualitative study was found that concluded that the three-dimensional methods were better for teaching visualization.

Devon (1992) and other instructors at The Pennsylvania State University conducted a study which dealt with three-dimensional "solids modeling" software being used in beginning engineering design courses. They administered a pre-Mental Rotation Test (MRT) and a post-MRT to several sections of a beginning freshman engineering design course. Their test included a group that was taught using traditional graphics methods and a group that was taught using three-dimensional computer graphics. Devon's study concluded that the use of "solids modeling" software and some three-dimensional wire-frame software contributed to an improvement in student (MRT) scores.

Another area that suggested strong support for implementing or using three-dimensional computer graphics was offered by those who proposed actual three-dimensional computer graphics curriculum models. Bertoline (1993) presented a model curriculum that stressed the importance of three-dimensional computer graphics in all levels of engineering design. Another conceptual model, offered by Bowers (1993), suggested that visualization was a component of a larger concept called "Imaging Science" which included all areas of engineering design. Related to Bowers' concept of Imaging Science was another curriculum model submitted by Wiley (1990). Wiley's model emphasized how "visual perception" was the key to engineering graphics and that three-dimensional computer techniques were important tools to visual perception. These curriculum models were considered to be conceptual and thus were based on theory only. The authors of the models did not include research data that supported their curriculum ideas.

Summary

The use of three-dimensional computer graphics is supported by research, education and industry. Because the use of three-dimensional graphics is a relatively new and emerging field, little has been researched or developed to support extreme changes in current curriculum delivery techniques. Many authors implied that three-dimensional methods should be used but they were uncertain about the extent. It was clearly stated in the literature, however, that three-dimensional computer graphics did have inherent advantages that allow a student to manipulate an object on a monitor and actually see how different sides of that object appear.

By using a three-dimensional model, a student can manipulate and observe an object on a computer monitor from different angles. This is a much more direct and meaningful learning experience than the two-dimensional techniques and principles (Bowers, 1993). Higher education researchers and instructors are now responsible for further developing new and innovative ways of using the advantages of three-dimensional procedures in "Engineering Graphics" curriculum design. The responsibility of higher education is to help students develop a sense of success in learning by eliminating all sources of frustration. On way of doing this is the incorporation of computer graphics into engineering design curricula (Nwoke, 1993).

CHAPTER III

METHODOLOGY

Introduction

The purpose of this study was to determine if beginning engineering design and drafting students should be taught visualization skills using three dimensional computer graphics. To accomplish this study, all engineering design graphics and drafting instructors at public Oklahoma colleges and universities were asked to complete a two part survey. All higher education institutions offering degrees in any type of engineering design were contacted by phone to determine if they offered courses pertaining to engineering graphics or CAD. Each institution that did meet the study criteria was then mailed a survey on October 7, 1994. The instructors were asked to return the survey by October 21, 1994. A geographical location map of those institutions that were mailed the survey is shown in Appendix F.

In the survey, the instructors were asked to answer a series of questions about their current curriculum and about their use of three-dimensional computer graphics. Research participants were also asked about the use of three-dimensional computer graphics as a tool for teaching visualization skills to beginning engineering design students. If a particular institution was not using computer graphics in their curriculum, the institution was not included in the study results. Thirty-eight surveys were mailed to Oklahoma engineering design graphics instructors. All research participants were mailed a cover letter (see Appendix A) and a two part survey (see Appendix B and C). For return purposes, a self-addressed, stamped envelope was also included.

survey. Of the 38 surveys mailed, 25 were returned. Only one survey was mailed to each research participant. No follow-up survey was needed. A 66 percent return rate was achieved with the first mailing. The instructor survey data was then compiled based on the survey criteria being satisfied. All institutions that were mailed a survey were asked to return the survey even if that institution did not meet the research requirements and assumption criteria. This was done to better evaluate the October 21 return date.

Subject Group

For this study, the subject group consisted of all engineering design graphics instructors from public Oklahoma colleges and universities. The subject group was chosen based on the existence of a college or university level engineering design or drafting curriculum at each institution. (See Appendix D for a list of institutions included in the study.) No private schools were included in this study.

Design

Part one of the survey (see Appendix B) was a questionnaire concerning the use of three-dimensional techniques in each instructor's curriculum. This part of the survey asked 13 questions concerning how engineering design graphics was taught at each institution. The final question on this part of the survey related specifically to how each instructor thought visualization skills should be taught, with or without three-dimensional computer graphics. A percentage rating was then calculated based on the number of surveys returned and the study limitations. Of the 25 returned surveys, six surveys were answered "Not Applicable" on questions 1 through 6 and seven surveys were answered "Not Applicable" on questions 7 through 14. To compute the percentage rankings, 19 surveys qualified for questions 1 through 6 and 18 qualified for questions 7 through 14.

Part two of the survey (see Appendix C) was a Likert type opinion poll asking the instructors to rank 20 concepts typical to engineering design curricula. This part of the survey was partially duplicated from a study conducted by Barr and Juricic (1989). Their study asked graphic educators to rank 120 curriculum items on a Likert type scale. Of the 120 items, Barr and Juricic published the top 20 with average rating scores. The top 20 items from Barr and Juricic's research were duplicated and included in this study. The 20 curriculum items were used on part two of the survey because of the heavy concentration of three-dimensional and visualization concepts.

By combining the two parts of the survey, a comparison could be made between the importance of engineering graphics course content and the use of three-dimensional computer graphics in freshman design courses. If visualization and three-dimensional computer graphics received high rankings on part one of the survey, they should receive comparable results on part two of the survey.

Ethical Considerations

Because state curriculum is publicly owned, permission to solicit information about each institution's curriculum was not necessary. All names of the participating institutions and instructors were kept confidential. All data from the surveys were kept confidential as well.

Summary

All public Oklahoma colleges and universities having a course in engineering design graphics or drafting were included in this research. Only schools that currently use computer graphics or CAD were included in the final research analysis. Only Oklahoma colleges and universities were surveyed. Each institution was asked the same survey questions. The primary concern of this study was to gather data as to what Oklahoma engineering design educators were doing with three-dimensional computer graphics and to determine if Oklahoma educators consider three-dimensional computer graphics to be a viable tool for teaching visualization skills. Once the questionnaires were completed and returned, the data were compiled and a statistical analysis of the survey was completed. The results from part one of the survey were compared to the results of Barr and Juricic (1991). (See Appendix E for Barr and Juricic results.)

CHAPTER IV

FINDINGS

The purpose of this study was to determine if beginning engineering design and drafting students should be taught visualization skills using three-dimensional computer graphics. A two part survey was used to facilitate this study. Part one of the survey was an opinion questionnaire and part two was a Likert attitude poll.

The findings for part one of the survey, shown in Table II, indicate that computer graphics are important to engineering design curricula. The data also supported a conclusion that visualization skills are important but are currently being taught predominately with two-dimensional techniques. When asked their professional opinion of the question, "Should beginning engineering design and drafting students learn visualization skills using three dimensional computer graphics?" a total of 50 percent of the instructors answered yes. But only 33 percent of those surveyed were currently using three-dimensional computer graphics techniques in their curriculum.

The findings for part two of the survey, shown in Table III, indicate that visualization skills are the most important topic in engineering graphics courses. The results of this part of the survey also suggest that two-dimensional techniques are more important than three-dimensional techniques when teaching visualization.

The results from both parts of the survey indicate that visualization skills are important, but a discrepancy exists in the method of teaching these skills. Barr and Juricic's study produced different findings as well (See Appendix E). Their study concluded that visualization skills were important, but the use of three dimensional computer graphics was the preferred method of instruction.

TABLE I

COMPILED RESULTS OF PART ONE OF INSTRUCTOR SURVEY

(See Appendix B for Survey Questions)

Question Number	Yes Response	No response	No Opinion
1	95 %	5 %	
2	84 %	16 %	
3	63 %	37 %	
4	42 %	58 %	
5	53 %	47 %	
6	95 %	5 %	
7	83 %	17 %	
8	28 %	72 %	
9	78 %	22 %	
10	100 %	0 %	
11	33 %	67 %	
12	89 %	11 %	
13	89 %	11 %	
14	50 %	22 %	28 %

TABLE II

AVERAGE SCORES OF PART TWO OF INSTRUCTOR SURVEY

Topic	Average scores (5 being top priority)
Visualization (2-D multiview)	4.95
Visualization (3-D solid model)	4.10
Visualization (natural free-form)	3.32
Visualization (2-D pictorial)	4.21
Visualization (3-D wireframe)	3.84
Visual relationship (3-D to 2-D)	4.63
CADD editing features	4.11
Dimensioning	4.63
Sketching	3.66
Freehand sketching (2-D pictorial)	3.63
Freehand sketching (natural free-form)	2.68
Freehand sketching media	2.53
Pictorials	3.53
3-D line and plane generation	3.58
3-D object transformations	3.68
3-D geometric construction	4.00
Base 3-D primitives	3.21
Combined 2-D CADD and 3-D solids	3.84
Solid (3-D) geometry	3.95
Knowledge/use of solid modeling	4.05

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to determine if beginning engineering design and drafting students should be taught visualization skills using three-dimensional computer graphics. The sources cited in this study implied that three-dimensional computer graphics were a viable tool for teaching visualization skills and that the tool should be investigated. The researchers cited in this study also suggested that the teaching of visualization skills with three-dimensional computer graphics was feasible.

Conclusions

The review of the literature suggested that three-dimensional graphics should be used. The type of three-dimensional graphics that was predominantly suggested was "solids modeling". The use of three-dimensional wire-frame was also suggested as a good tool for teaching visualization but it lacked the realistic viewing features offered by the solids modeling method.

The data gathered in this study from the Oklahoma engineering design graphics instructors indicated that the use of three-dimensional computer graphics should be used. While the results were not overwhelming, a majority of the qualified research participants did advocate the use of computer graphics for teaching visualization skills. Many research participants indicated that they were not currently using three-dimensional computer graphics as a visualization teaching tool, but they did agree that the idea had merit. From the survey results, it was concluded that three-dimensional computer graphics could be used as an alternative teaching method.

Recommendations

Current computer software and hardware offer the opportunity to work immediately in three dimensions. Three-dimensional computer modeling appears to be a viable replacement for either two-dimensional techniques or physical three-dimensional models or scaled prototypes (Bolluyt, 1993). Three-dimensional techniques have changed the importance of and the integration of engineering graphics into higher education curriculum (Kitto, 1994). The sources cited and the instructors surveyed in this study agreed that using three-dimensional computer graphics to teach visualization skills to entry level engineering design students was feasible. The extent to which three-dimensional computer graphics is to be used remains uncertain, but support for the idea was apparent and does warrant further investigation.

It is recommended that advanced studies be done on groups of students entering engineering design curricula. These studies should focus on the use of three-dimensional computer graphics in a beginning engineering design course where visualization is first introduced. It is also recommended that "solids modeling" be used as the primary three-dimensional design tool due to its advanced capabilities over the other forms of software.

If techniques can be developed that will enable students to use current industrial technology in the classroom, a better educated and prepared student could emerge from colleges and universities across the United States. Institutions of higher education have the responsibility and obligation to develop the curriculum that will meet the needs of students and the needs of industry. The use of three-dimensional computer graphics is just one of the many concepts requiring attention in this blending of technological theory and reality.

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APPENDIX A

TRANSMITTAL LETTER

MAILED TO OKLAHOMA COLLEGE AND

UNIVERSITY ENGINEERING DESIGN

GRAPHICS INSTRUCTORS

I am conducting research for a master's thesis and would appreciate your help. Enclosed with this cover letter is a two part survey concerning the way beginning engineering design graphics and beginning CAD should be taught at the college level. Only college instructors teaching CAD in Oklahoma are being surveyed. The results of this research will be used to complete a master's degree in Technical Education at Oklahoma State University.

The object of the survey is as follows: Should beginning engineering design students learn visualization skills using three dimensional computer graphics? This research centers on the use of 3D computer graphics as a beginning teaching tool in freshman design courses.

Any cooperation that you could give would be greatly appreciated. It is my hope that the information obtained with this research will be used, not only to complete my thesis, but to also better prepare college level drafting curricula. If you are no longer involved with CAD instruction but know an instructor who is, I would appreciate the forwarding of this survey.

Please return the survey in the enclosed self-addressed, stamped envelope by October 21, 1994. If you have any questions, please call me at (405) 581-2348. Thank you for your valuable time and input.

Sincerely,

Bobby Taylor
Technology Instructor

APPENDIX B

INSTRUCTOR SURVEY - PART ONE

MAILED TO OKLAHOMA COLLEGE AND UNIVERSITY ENGINEERING DESIGN GRAPHICS INSTRUCTORS

Engineering Design Graphics Instructor Survey - Part One

Instructor Name: ______________________________(Optional)
Institution: ______________________________(Optional)
Please circle your response to the following questions. No other responses are required.

1. Are you a Computer Aided Design/Drafting (CAD) instructor at your institution?
Yes No

2. Do you teach Mechanical (Machine) design/drafting?
Yes No

3. Do you teach Architectural design/drafting?
Yes No

4. Do you teach Civil design/drafting?
Yes No

5. Do you teach Electrical design/drafting?
Yes No

6. Do you currently use Computer Aided Drafting (CAD) in your curriculum?
Yes No
(If "No", you do not need to complete Part One of the survey. Please complete Part Two of the survey and mail back both parts in the provided envelope.)

7. Do you currently teach drafting with CAD combined with Traditional (manual) drafting?
Yes No

8. Do you use CAD exclusively?
Yes No

9. Do you use 2D (Orthographic) CAD to teach beginning drafting students visualization skills?
Yes No

10. Do you use 3D CAD in your design/drafting curriculum?
Yes No

11. Do you use 3D CAD to teach beginning drafting students visualization skills?
Yes No

12. Is 2-D freehand sketching a part of your design/drafting curriculum?
Yes No

13. Is 3-D freehand sketching a part of your design/drafting curriculum?
Yes No

14. What is your professional opinion on the following question?
Should beginning engineering design and drafting students learn visualization skills using three dimensional computer graphics?
Yes No No opinion

APPENDIX C

INSTRUCTOR SURVEY - PART TWO

MAILED TO OKLAHOMA COLLEGE AND

UNIVERSITY ENGINEERING DESIGN

GRAPHICS INSTRUCTORS

Engineering Design Graphics Instructor Survey - Part Two

Rank each of the following items on the level of importance with 5 being top priority and 1 being the lowest priority.

1.	Visualization (2-D multiview)	1 2 3 4 5
2.	Visualization (3-D solid model)	1 2 3 4 5
3.	Visualization (natural free-form)	1 2 3 4 5
4.	Visualization (2-D pictorial)	1 2 3 4 5
5.	Visualization (3-D wireframe)	1 2 3 4 5
6.	Visual relationship (3-D to 2-D)	1 2 3 4 5
7.	CADD editing features	1 2 3 4 5
8.	Dimensioning	1 2 3 4 5
9.	Sketching	1 2 3 4 5
10.	Freehand sketching (2-D pictorial)	1 2 3 4 5
11.	Freehand sketching (natural free-form)	1 2 3 4 5
12.	Freehand sketching media	1 2 3 4 5
13.	Pictorials	1 2 3 4 5
14.	3-D line and plane generation	1 2 3 4 5
15.	3-D object transformations	1 2 3 4 5
16.	3-D geometric construction	1 2 3 4 5
17.	Base 3-D primitives	1 2 3 4 5
18.	Combined 2-D CADD and 3-D solids	1 2 3 4 5
19.	Solid (3-D) geometry	1 2 3 4 5
20.	Knowledge/use of solid modeling	1 2 3 4 5

If you would like to receive a copy of the results of this survey, please print your name and address below, or enclose a business card.
Thank You for you input!

APPENDIX D

OKLAHOMA COLLEGES AND UNIVERSITIES

MAILED INSTRUCTOR SURVEY

Cameron University
2800 W Gore Blvd.
Lawton, OK 73505

Connors State College
Warner, OK 74469

Murray State College
1100 S. Murray
Tishomingo, OK 73460

Northern Oklahoma College
1220 East Grand Ave.
Tonkawa, OK 74653

Northeastern Oklahoma A & M College
200 Street NE
Miami, OK 74354

Northeastern State University
Tahlequah, OK 74464

Northwestern State University
709 Oklahoma Blvd.
Alva, OK 73717

OKC Community College
7777 South May Ave.
Oklahoma City, OK 73159

OSU-Okmulgee
Okmulgee, OK 74447

OSU-OKC
900 North Portland
Oklahoma City, OK 73107

Oklahoma State University
Stillwater, OK 74078

Rose State College
6420 S.E. 15th
Midwest City, OK 73110

Southeastern O.S.U.
Durant, OK 74701

Southwestern O.S.U.
Weatherford, OK 73096

Tulsa Junior College
3727 E. Apache
Tulsa, OK 74115

University of Oklahoma
660 Parrington Oval
Norman, OK 73019

Western Oklahoma State College
2801 North Main
Altus, OK 73521

APPENDIX E

BARR AND JURICIC RESULTS

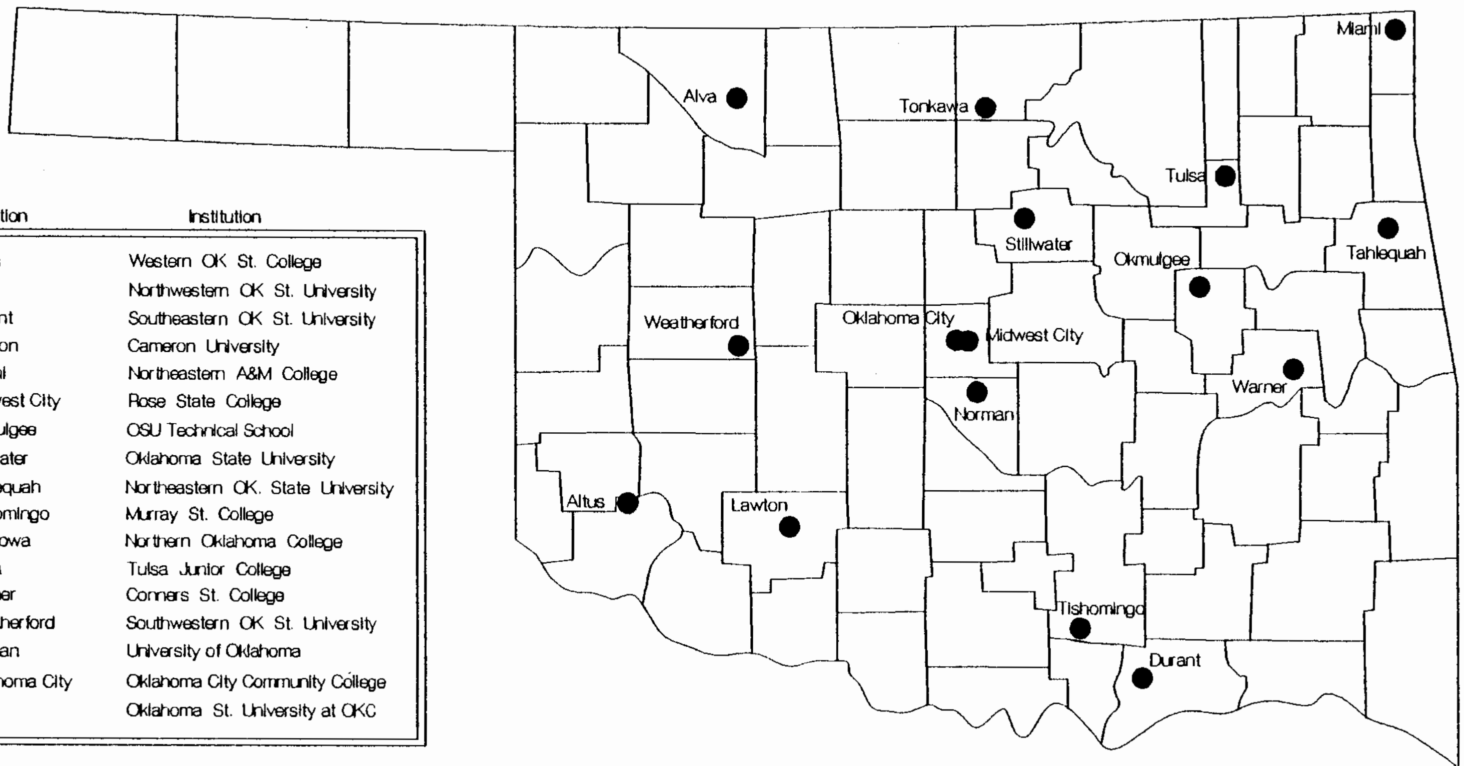
Topics	*Average Rating***	*Topics*	*Average Rating***
Visualization (3-D solid model)	4.667	3-D line and plane generation	4.333
3-D geometric construction	4.583	Pictorials	4.250
Visualization (natural free-form)	4.500	Freehand sketching media	4.167
Sketching	4.500	Freehand sketching (natural free-form)	4.167
3-D object transformations	4.500	Visualization (2-D pictorial)	4.167
Knowledge/use of solid modeling	4.333	Visualization (3-D wireframe)	4.091
Solid (3-D) geometry	4.333	Freehand sketching (2-D pictorial)	4.083
Visual relationship (3-D to 2-D)	4.333	Dimensioning	4.083
Combined 2-D CADD and 3-D solids	4.333	CADD editing features	4.083
Base 3-D primitives	4.333	Visualization (2-D multiview)	4.000

* Out of a total of 120 items. ** Based on a scale of 5=top priority and 1=lowest priority.

APPENDIX F

GEOGRAPHICAL LOCATION MAP OF OKLAHOMA

INSTITUTIONS INCLUDED IN THE STUDY



Location	Institution
Altus	Western OK St. College
Alva	Northwestern OK St. University
Durant	Southeastern OK St. University
Lawton	Cameron University
Miami	Northeastern A&M College
Midwest City	Rose State College
Okmulgee	OSU Technical School
Stillwater	Oklahoma State University
Tahlequah	Northeastern OK. State University
Tishomingo	Murray St. College
Tonkowa	Northern Oklahoma College
Tulsa	Tulsa Junior College
Warner	Conners St. College
Weatherford	Southwestern OK St. University
Norman	University of Oklahoma
Oklahoma City	Oklahoma City Community College
	Oklahoma St. University at OKC

Goegraphical Location Map of Oklahoma Institutions Included in the Study
(Courtesy of Cameron University Technology Department)

VITA

Bobby Don Taylor

Candidate for the Degree of

Master of Science

Thesis: A STUDY TO DETERMINE IF BEGINNING ENGINEERING DESIGN AND DRAFTING STUDENTS SHOULD LEARN VISUALIZATION SKILLS USING THREE DIMENSIONAL COMPUTER GRAPHICS

Major Field: Technical Education

Biographical:

Personal Data: Born in Durant, Oklahoma, On October 23, 1966, the son of Ken and Lorinda Taylor.

Education: Graduated from Chattanooga High School, Chattanooga, Oklahoma in May 1984; received Bachelor of Science degree in Technology and an Associate of Science degree in Design Drafting from Cameron University, Lawton, Oklahoma in May 1988. Completed the Requirements for the Master of Science degree with a major in Technical Education at Oklahoma State University in May 1995.

Experience: Employed by Halliburton Services, Duncan, Oklahoma as a mechanical designer in the Manufacturing Engineering Department, 1988 to 1990; employed by Cameron University, Lawton, Oklahoma, Department of Technology as an instructor, 1990 to present.

Professional Memberships: American Design Drafting Association; American Society for Engineering Education; American Technical Education Association; Oklahoma Technical Society.

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 01-03-95 **IRB#:** ED-95-027

Proposal Title: A STUDY TO DETERMINE IF BEGINNING ENGINEERING DESIGN AND DRAFTING STUDENTS SHOULD LEARN VISUALIZATION SKILLS USING THREE-DIMENSIONAL COMPUTER GRAPHICS

Principal Investigator(s): Gary Oakley, Bobby Taylor

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): None

APPROVAL STATUS SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING.
APPROVAL STATUS PERIOD VALID FOR ONE CALENDAR YEAR AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Reasons for Deferral or Disapproval are as follows:

IF THE APPLICATION HAD BEEN SUBMITTED IN A TIMELY MANNER, IT WOULD HAVE BEEN APPROVED AS EXEMPT.

Signature: John H. Wycoff [signature]
Chair of Institutional Review Board

Date: January 3, 1995