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THE IMPACT OF COMPUTER GRAPHICS ON INSTRUCTION IN ENGINEERING GRAPHICS: IMPLICATIONS FOR CURRICULUM DEVELOPMENT

by

Jon K. Jensen, A.A., B.S., M.S.

A Dissertation Submitted to the Faculty of the Graduate School, Marquette University, in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Milwaukee, Wisconsin
April, 1985

3.) To determine the level of importance placed upon identified skills or curricular experiences by academia and the level of provision for these skills that engineering students receive.

4.) To identify and describe any differences that exist between levels of importance and levels of provision of identified skills and experiences, within the two groups.

5.) To identify and describe any differences that exist between levels of importance and levels of provision of identified skills and experiences, between the two groups.

6.) To identify what types of hardware and software are being used to achieve curricular objectives in engineering graphics, and what configurations appear to work well in an educational environment.

RESEARCH QUESTIONS

Based on the purposes of the study, the following research questions were proposed:

1.) What set of classroom curricular experiences are identified in the literature as experiences that are needed or desired to prepare employees for computer graphics use in industry.

2.) What is the level of importance and the level of provision placed upon identified skills or curricular experiences by industry, relating to computer graphic preparation, and what additional skills exist, if any.

3.) What is the level of importance and the level of provision placed upon identified skills or curricular experiences by academia, relating to computer graphic preparation and what additional skills exist, if any.

4.) What differences exist, if any, between mean levels of importance and mean levels of provision of identified skills, within groups.

5.) What differences exist, if any, between mean levels of importance and mean levels of provision of identified skills, between groups.

6.) What specific hardware and software are being used by engineering schools to support curricular objectives in engineering graphics?

NEED FOR THE STUDY

Engineering graphics is a important part of the engineering curriculum. Computer graphics needs to be implemented into the curriculum if the engineering college intends to be responsive to the times. There is relative agreement about what constitutes valid objectives of a traditional engineering graphics course, but, not when it concerns computer graphics. Much has been written in the literature about new and developing programs using computer graphics. An examination of the literature, however, suggests that there is a little agreement on what skills or curricular experiences are needed. In addition, monetary resources in an educational setting must be utilized as efficiently as possible. Any information which assists in making these decisions is of paramount interest to educators and administrators. The decisions made for curricular objectives will have a direct effect on the decisions made for hardware and software purchases. To further support the need for this research, a draft of this proposal was sent to two respected university professors who are active in engineering graphics and computer graphics. Professor Ronald E. Barr of the University of Texas-Austin has been cited several times in the review of literature and represents a particular viewpoint on this subject. Professor Robert LaRue of Ohio State University has also been cited in the literature and represents an alternative viewpoint on the subject. Their cooperation and support is shown in letters to that effect included in Appendix A.

SIGNIFICANCE OF THE STUDY

The engineering graphics community does not agree on the purpose and direction of the curriculum in computer graphics. Therefore, if a form of substantive evidence for making curricular changes were available, the decision making process could be enhanced. The results of this study could be a valuable resource to those institutions and graphicians who require information in order to make decisions about computer graphics curricula.

DEFINITIONS

CAD - a term which means Computer-Aided Design. It is the technology concerned with the use of computers to perform specified functions in engineering design, such as creation, modification and analysis.

CADD - a term which means Computer-Aided Design and Drafting. It is the technology concerned with the use of computers to perform specified functions in automated drafting.

CAM - a term which means Computer-Aided Manufacturing. It is the technology concerned with the use of computers to perform specified functions related to manufacturing and production, such as planning, managing and controlling operations.

Computer Literacy - a general understanding of electronic computing; an area of knowledge that includes 1.) understanding the technology of information processing 2.) understanding of the effects that computers have and will have on Society, and 3.) understanding how computers are problem- solving tools. (Horn and Poirot p. 340)

Computer Graphics - the generation, display, and manipulation of geometric object information with the aid of a computer.

Engineering Graphics - a term used to denote a part of technical drawing concerned with graphic representation of designs, specifications, and data relationship for science and industry. (Giesecke p. 8)

Geometric Model - a mathematical abstract description of the geometric elements composing an object for the purpose of generating a computerized visualization either on a computer system or plotter device.

Computer Hardware - each piece of physical equipment composing a computer system.

Computer Programmer - a person who designs and implements sets of instructions, or programs, used internally by computers.

Computer Software - the name given to computer programs that are input into a computer.

Computer User - the person who inputs data into and receives feedback from a computer system.

Turnkey

System - a commercial system that is delivered by a vender, installed, checked out and provided in a form ready to use.

LIMITATIONS

Computer graphics has had a great effect on engineering in general and that effect has broad implications for engineering education. However, this study is limited to research and data collection in the area of impact on the engineering graphics Curriculum. There is no intention to draw conclusions in regard to a total engineering curriculum. The results of this study are aimed at engineering programs rather than technology or vocational programs.

The results of this study are limited by the use of the survey instrument which was developed for this study. Differences in some item mean values may have been produced by the instrument itself, and are noted in the analysis where appropriate. The technical terms used on the instrument were intended to be understood in their broadest sense of the definition. However, these terms may have been understood in different contexts by different populations.

CHAPTER II

REVIEW OF RELATED LITERATURE

Computer graphics has received a great deal of attention in recent years. Much has been written about how this technology is changing the complexion of engineering graphics and engineering education in general. To assist in understanding, the review of related literature will be examined from two viewpoints: 1.) an industrial viewpoint that describes what industry desires of engineering graduates, and 2.) an academic viewpoint, that describes what is currently being accomplished by engineering schools to meet these needs.

Industrial Viewpoint

Although much of the literature in this area is written by academic authors, several have investigated industrial applications of computer graphics. Harvey (1970) studied what was available in computer graphics for industry. He attempted to determine what equipment was suitable for freshman engineering and technology students and the capabilities and requirements of contemporary systems. Although he does not address the specific idea of curricular objectives, his findings dc lead to some useful conclusions. He recommends that engineering graduates should have a solid foundation in spatial visualization and graphical communication. These skills are usually provided in a course in Engineering Graphics. However, he also states that to be effective the graduate should also be aware of what computer graphics equipment can do to make the process faster, more effective and more complete. Harvey also states that he believes that all freshmen should have experience with a commercial computer graphics system following a unit of basic graphics. This may be a very difficult thing to do in consideration of the expense involved, but, also of importance is the fact that he feels freshmen should have a unit in basic engineering graphics before using computer graphics.

McDougal (1981) surveyed industry to discover what functions CAD and CAM technology were being used for. The results indicate that the most common use of CAD is in the areas of; the design of machine elements and in electrical circuit boards; the solution of problems using finite element analysis and interactive graphics design. In addition to CAD/CAM, Computer-aided drafting (CADD) was indicated as being a system function. All of the survey respondents indicated that they were using CAD to perform design work and solve problems. However, 75% of the respondents indicated that they were using CAD to perform Computer-aided Drafting. The survey supplies information about what areas of CAD/CAM are most utilized by industry. McDougal concludes that "There is sufficient interest and application of CAD/CAM in industry to make it a required (or optional) subject for all undergraduate and graduate engineering students". While the design of machine elements, circuit boards and finite element analysis are not part of an engineering graphics course, aspects of basic drafting are.

Problem solving, as a skill is stated many times in the literature as a needed skill. However, problem solving skills manifest themselves differently depending on the problem at hand. Bluhm (1981) points out the need for graphic communication as a problem solving tool of the engineer. He discusses the importance of computer graphics today and what industry needs from universities. Bluhm presents three challenges to universities; 1.) to provide graduates who are trained to define analytically, in 3-dimensional terms, a geometric object. 2.) to provide graduates who can convert data into information, and 3.) to provide graduates who can use information to create a better product and a better tomorrow.

While the above challenges are a bit vague, Bluhm is calling for computer literate engineers or people who know how to use the new computerized tools. Challenge number 1 above addresses a need for engineers who can understand the geometry of objects and enter that data into a computer data base. This skill is most commonly known as geometric modeling. Asking universities to produce graduates who are intuitive and creative in using information, is a difficult request within any curriculum. However, in engineering, these attributes can relate directly, and can be observed, in the way one uses resources to solve problems.

Shephard (1981) discusses the university's role in preparing students to be productive workers in our computer oriented industrial environment. He begins by defining what industry's needs are and the describing what R.P.I. is doing in this area. The major need, according to Shephard is for staff who are proficient at using interactive computer graphics techniques to solve engineering problems. This statement is directed at producing personnel who are "users" of computer graphics and for problem solvers. In addition, he feels that engineers should be able to do computer programming for computer graphics. There is no mention of any need for skills in basic engineering graphics. Some schools in this country have eliminated this topic from their programs, for a variety of reasons. This fact seems evident in the tone and direction of Shepards discussion, but is none-the-less useful in developing a working list of needed graphic skills.

A two year program of equipment aquisition, curriculum modification and faculty development was implemented at Southern Methodist University to address the need for Computer literate engineers for industry. Bluhm and Lovas (1981) describe how the program addressed 5 areas including computer graphics and CAD/CAM technologies. In the area of computer graphics, the authors state that geometric principles and procedures are the basis for skills. Five objectives were developed to guide their actions, 1.) be able to program and operate a computer graphic system, 2.) be able to display equations and mathematical forms, 3.) be able to create mathematical formulations to satisfy known or desired constraints, 4.) be able to generate engineering drawings with Computer-Aided Drafting software, 5.) be able to rotate and translate objects in 3-dimensional geometry.

Objective 1 and 2 above address the need for programming and "user" skills. Objective 3 relates to many areas of engineering and in essence - problem solving. Objectives 4 and 5 express a need to be able to perform computer aided drafting and related geometric functions which encompass geometric modeling.

The bachelor degree in engineering has the broadest base of fundamental principles, and the least training in specific job skills. This usually means that while the engineer is basically prepared for an engineering position, it may require that he receive additional training from his employer. To know what computer graphic and CAD skills the graduate should have requires examination of the design process. In defining curricular objectives for engineering programs, Carpenter (1982) also describes what occurs in industry and this can be applied to what engineers should know. He describes the flow of a design project from the engineer to the technician, where the engineer is involved with the conceptual area of design. Computer-Aided Design involves using a workstation to generate models which are then analyzed by Computer programs allowing interactive modification of the model until a satisfactory design is obtained. Carpenter points out that it is only then that Computer-Aided Drafting is accomplished, and then, not by an engineer, but by a technician. By describing this process, commonalities appear, namely geometric modeling and analysis. However, Carpenter sees the Computer-Aided Drafting skills as unnecessary at the engineers level.

A survey was conducted by Jeswiet and Surgenor (1984) to determine what industry wanted from engineering graduates in Canada. Their survey objective parallels one objective of this study except that this study is limited to applications to engineering graphics. Thirty-two industries were polled and 24 responses were received. The responses were quite useful in gaining a perspective of the options for change that were open to engineering Curriculum developers. Canadian industries reported, among other things, that graduates should have experience with Computer-Aided Drafting and systems analysis. The survey also showed a desire for graduates to have experience on both large main frame computers as well as microcomputers. In the area of computer languages, the survey indicated that graduates should have knowledge of a variety of languages.

Not all responses have a direct application to the present study but many comments do. Almost all respondents indicated a need for continued instruction, and expansion, in the area of engineering graphics early in the core curriculum, and more exposure to computers. Based on the results of the survey a number of recommendations were made to improve the curriculum. Among the proposed changes was to revise a present course in engineering graphics to include an introduction to computer graphics.

A university needs to adapt to changes that are occuring in business and industry. In most cases, industry leads and universities follow. However, universities can also provide a certain amount of leadership to industry by introducing students to new technologies, methods; etc., thus, making industry more productive in the process. Zeid (1983) describes a university/industry collaboration model that has been implemented at Northeastern University. As a result of a large equipment grant they have been able to bring Commercial CAD/CAM technology into the classroom. The industrial support that they receive as a result also improves the quality of instruction. Providing for interacting with industry is no different than providing for instruction in any particular subject. However, this interaction can in some instances become very site dependent. Large industrial communities are probably able to offer urban colleges a higher quality of interaction.

The training of CADD operators is usually performed in technology or vocational program areas. While the skills of the CADD operator are of interest to engineering educators, engineering graduates will not ordinarily need these same skills. Fox (1984) performed a study to determine what specific training was required or desired by industry. The results of his study were used in the implementation of various hardware and software systems at his institution. Fifty percent of the respondents indicated that no knowledge of computer programming was necessary to efficiently operate a CADD system. Among other useful results were that 60% of the respondents felt that students needed improvement in basic drafting skills, BASIC and FORTRAN programming, typing, geometry and mathematics. The type of CADD system used in the learning process was not deemed significant.

Academic Viewpoint

In reviewing the literature relating to the academic viewpoint of the computer graphics curriculum, two subdivisions can be generated. There is a body of literature that describes, in a general sense, what the curriculum should consist of with regard to computer graphics in engineering graphics. There is also a body of literature that relates research and experiences at specific colleges and universities. The purposes of this review are to examine what engineering educators perceive to be "good" curriculum design, and what curriculum activities are taking place in engineering graphics with regard to implementation of computer graphics technology.

Engineering professors have implemented computer graphics into many courses. Today the computer is being applied to many courses where it previously had not been applied. However, this proposed study will deal with computer graphics implemented into engineering graphics courses. This is seen by many as a logical place to begin an experience in computer graphics. Ryan (1980) described a 3-semester-hour course at Clemson University where computer graphics has been implemented. He makes a recommendation for a ideal situation that includes a two course sequence; one of basic engineering graphics and one of computer graphics. The first course should contain as little programming as possible. The second should merge graphics topics with other engineering courses. Ryan makes a good case for computer graphics within engineering graphics courses but, a two semester sequence is not the most commonly found situation. Wyman (1981) found that the average credit hour requirement in engineering graphics was 2.42, and 11% of the respondents to his survey required no graphics courses at all. Less than 1% of the schools surveyed by Wyman in 1981 were operating computer based programs.

Barr, Wood and Juricic (1984) describe a curriculum at the University of Texas-Austin where a plan for implementation of computer graphics has been proposed to include all four undergraduate years. The authors state that there is little arguement that computer graphics should begin in freshman level engineering graphics. However, they propose that an optimum implementation would include a combined graphics, design and programming sequence. Beil (1980) also asked questions about which concepts of engineering graphics and computer graphics should be taught to freshmen? He concludes that: 1.) Computer graphics should be included in the freshman year and should include some programming. 2.) Computer graphics may or may not be part of traditional engineering graphics courses. 3.) Students should learn to use software programs for graphing and drawing, and also to write programs to do the same.

An informal survey was conducted by the Computer Graphics Committee of the Engineering Design Graphics Division of ASEE in 1982 to determine the implementation of computer graphics and CAD early in the undergraduate education. Selected results of the survey show the computer graphics is usually first introduced within the course in engineering graphics (51.6%). Nineteen percent indicated that computer graphics is introduced in a computer programming course. Computer programming was also the second most popular method at introducing computer graphics in a freshman program. Most of the respondents indicated that computer graphics was taught using large mainframe computers and using software that was developed within that school. This survey is valuable in assessing the relative state of affairs in teaching computer graphics where ever it is being taught. However the survey falls short of appraising the adequacy of what is being done in view of industrial needs. The survey does not help the reader to evaluate his own situation. Three important conclusions were developed (however) as a result of this survey and relate to the present study; 1) computer graphics should be introduced in the freshman year with the most logical place being an engineering graphics course. 2) No computer programming need be covered in this course due to the interactive nature of todays software but may be helpful. 3) A second-level engineering computer graphics course should become part of the curriculum.

Ever since its emergence and introduction to engineering applications, computer graphics has been associated with engineering graphics. Juricic and Barr, (1984) however, argue that computer graphics and engineering graphics do not belong together. The two authors have done a great deal of curriculum development work at the University of Texas-Austin. The basic thrust of their effort has been to define what a course in engineering graphics should be in view of this computer graphics age. Juricic and Barr Contend that engineering graphics and computer graphics have little in common except name. They propose that a modern engineering graphics course would use computer graphics as a tool through which students would perform computer aided design and drafting. Otherwise, the course would reflect a traditional course in engineering graphics. Computer graphics would then be treated as a separate level topic and should then rate being a course in itself. The computer programming activities sometimes associated with computer graphics would not be performed within engineering graphics course. The authors have made a good case for the design of their proposed curriculum. In addition a perspective taken from the viewpoint of an industrial setting would further support the rationale for their decisions. If engineering education has as one purpose, to support industry, then it must listen and be responsive to industry's needs.

Jenison and Vogel (1982) point out that industry is indeed expecting universities to provide graduates who have expertise in engineering graphics and computer graphics. Their work supports the need for research in the area of curriculum development in engineering graphics. They state four questions that need to be answered; 1) What should be in a present-day engineering graphics program; 2) how an adaquate preparation in graphics can enhance learning in advanced courses; 3) what employers expect the new engineering graduate to know and to be able to do; and 4) what constitutes functional literacy in graphics and how much time is needed to aquire the necessary knowledge and skills. Jenison and Vogel also indicate a problem experienced in general by most academic units. That is, if a new topic is going to be added to the curriculum, what will be eliminated? From their observations, they make several conclusions of interest, including; 1) additional time for engineering graphics in the curricula will not be allotted; 2) the solution lies in better use of educational time; 3) the solution requires a merger of engineering graphics instruction with computer graphics. The third conclusion is in direct opposition to the previous citation by Juricic and Barr who make an interesting case for separation of the two topics completely. It would appear that research into this area of curriculum development is justified and needed to provide a substantive rationale for decision making.

The computer presents a "highly complex, controversial and perhaps unavoidable challenge for engineering graphics educators," states Ross (1984, p. 25). He also describes how the faculty at North Carolina State University have taken steps to develop their curriculum in this expanding area. Although there is little explanation of their rationale, phases of implementation and objectives are given. Several points appear to be of interest, including a basic overall focus on engineering graphics fundamentals regardless of depth of computerized implementation. This would indicate either that computer graphics is implemented into a traditional, fundamental course in engineering graphics, or that computer graphics is a second or additional course of instruction. As a matter of preparation by the university for this inclusion in the curriculum, a number of goals were established, among which were the following: establish contacts with industry and business, survey other university engineering graphics programs and review available literature. These goals are very much congruent with the present study.

The historical development of engineering graphics was examined by Duane (1984) in an attempt to place the present curriculum situation in proper perspective. The history of engineering graphics shows a progressive decrease of the number of credit hours required. Some engineering schools even progressed to a point where engineering graphics was eliminated from the curriculum. Duane points out that industry today is developing a new kind of engineering graphics involving analysis technique. The engineer will again need engineering graphic skills to be competent in his/her field. The jobs that were given to technicians will be performed again by engineers. In the conclusion of her paper, Duane proposes that a study be done to address the following questions; 1) what is the subject matter that comprises modern engineering graphics, and 2) how can this body at knowledge be taught to engineers. The present study intends to directly undertake question 1 and indirectly, question 2. The concerns elaborated by Duane are in no way unique to the literature. The number of authors who are asking important questions like these appears to be growing, and supports the effort of the present study.

Additional evidence of the lack of direction in the implementation of computer graphics into the engineering graphics curriculum is seen in an article by Nasman (1984). Ohio State University has been a leader in the general area of CAD implementation for several years, and yet there are still questions being voiced in regard to the objectives of their programs. Nasman indicates that the real problem is deciding just what the instructional objectives are for having computer graphics hardware, and deciding where it fits into the curriculum. While he has been primarily concerned with the use of microcomputers and computer graphics, his questions have validity for all areas of computer graphic implementation - especially the engineering graphics curriculum. It begins to become clear that the questions expounded in the literature are questions that need to be answered in some substantive way. If the computers and computer graphics are here to stay, then we need to be able to deal with the questions of how to implement this important technology.

Obtaining a functioning computer graphic system can be an expensive process. Shephard (1981) explains that obtaining monies to buy a system is not a simple task, and the variety of systems available does not make the problem any easier to solve. He also states that obtaining hardware to do computer graphics is only part of the problem. The software is critical to the functioning of the system and to the intended objectives of the curriculum. Even though this process is difficult, a number of universities have developed facilities. However, there is no general consensus as to what is the most effective way of implementing computer graphics into the curriculum.

SUMMARY

Literature Related to the Industrial Viewpoint

Industry, as a consumer of engineering graduates, desires graduates who can serve effectively and whose training is a reflection of a responsive educational program. The literature exposes several skills and/or curriculur experiences which have been directly or indirectly recognized. Examination of the literature also shows that several authors have the same or similar feelings. While there is some disagreement, most of the citations reflect general agreement as to these items. After analyzing the literature, the following list of skills or experiences can be established:

1) 3-D geometric modeling
2) computer-aided drafting
3) computer programming for computer graphics
4) problem solving analysis with CAD
5) system "user" skills
6) experience with commerical CAD system.

These skills all have application to computer graphics in some way. In addition to these skills, many of the authors express a need for more traditional skills as well. These skills are:

1) traditional engineering graphics
2) sketching
3) spatial visualization
4) descriptive geometry

Several authors feel that there is a need for an expansion in these traditional areas.

Literature Related to the Academic Viewpoint

Most authors appear to agree that engineering colleges must support the needs of industry. However when it comes to defining what these needs are there is little agreement. There is also little agreement on what good curriculum design consists of for computer graphics. Points of commonality do emerge, however. Almost all of the authors in the reviewed literature feel that the logical place to begin a computer graphic experience is in a freshman program. Many authors feel that this means the experience will be received within a course in engineering graphics. Computer programming as a needed skill is mentioned in several citations. However, until recent years this appeared to be the only way to teach computer graphics. Today there is much more available in the way of software so that other experiences can be realized.

After reviewing this literature, the following observations can to be made in addition to the above. There is a pervading question throughout the literature about what the curriculum in engineering graphics should now contain. The literature asks many more questions of this nature than it offers solutions. This section of the literature also directly supports the need for scholarly research in curriculum development for engineering graphics.

CHAPTER III

METHODOLOGY

Introduction

The purpose of this chapter is to describe the research plan, including survey instrument, selection of samples, data collection and processing, and analysis of the data.

This study was directed at determining the impact of computer graphics on instruction in engineering graphics. The results of the study are intended to assist curriculum planners and developers in the design of an engineering graphics curriculum which includes provision for modern computer graphics methods. The objectives of the study were accomplished in three phases.

Phase 1 of the study involved a systematic search and review of the literature related to the needs of industry in the area of computer graphics skills. This search was accomplished, in part, with the aid of computerized library searching methods and other manual methods. The information obtained from this portion of the literature review was used to compile a list of skills or curricular experiences that industry feels engineering graduates should possess. This list of skills and experiences were then used to develop and construct a survey questionnaire relating to the engineering graphics curriculum.

literature search in phase 1 of the study, a self reporting questionnaire was developed. To complete the questionnaire responses, four items were added; experiences with CAD using microcomputer systems, experiences with CAD using mainframe computer systems, computer graphics, and a combination of traditional engineering graphics and computer graphics. In order to measure "how important" a skill is and "how well" it is provided, a Likert-type scale was used. The scale contained addressable values from a low of 1 to a high of 5. The example below shows the general layout of a sample item.

HOW IMPORTANT	SKILLS	HOW WELL PROVIDED
1 2 3 4 5	Descriptive Geometry	1 2 3 4 5

The main body of the questionnaire contains 14 items with the above arrangement of response. Respondents were given instuctions in regard to the basic operation of the scales and procedure. A value of 1 indicates a LOW importance or LOW provision and a value of 5 indicates a HIGH importance or HIGH provision. No attempt was made to delineate values between 1 and 5. The two populations responded to the same skill items, but individual procedures were slightly different. The industrial sample was asked to respond as to "how important" a skill is to engineers, and "how well" that skill is being provided in the graduate engineers they hire. The academic sample was asked to respond as to "how important" they feel a skill is to engineers, and "how well" students are provided instruction in this area.

In addition to the main body of the questionnaire, the academic sample was also questioned about the software and hardware system(s) that are being used to achieve their instructional objectives. Six items were constructed to solicit information. Two of the items request information about the type of hardware and software used to achieve objectives in engineering graphics. Two corresponding items request a personal appraisal of these systems on a response scale including; poor, fair, good, very good or excellent. The remaining two items solicit write-in information about the specific (named) type of hardware and software. In order to determine the content validity of the instruments, they were displayed to 3 industrial representatives and 3 academic representatives. After this examination, a determination of content validity was made. Their comments and suggestions about the individual items and format were very helpful and contributed to successful implementation of the survey. After the data collection was complete, a reliability estimate of each instrument was determined by calculation of coefficient alpha (α). The reliability of the industrial survey instrument is reported as $r_{xx'} = .775$, and the reliability of the academic survey instrument is reported as $r_{xx'} = .981$. Appendix B contains a sample of the questionnaire which was mailed to industrial respondents. Appendix C contains a sample of the questionnaire which was mailed to the academic respondents.

COLLECTION OF THE DATA

The two survey instuments were distributed by mail. Each mailing contained a personalized cover letter explaining the purpose and importance of the questionnaire, the survey instruments, and a self addressed, stamped envelope. All mailings within each sample were identical. A system of coding the return envelopes was used for the purpose of limiting a follow-up procedure. Because of the timely interest in the topic and the non-threating nature of the instruments, anonymity was not considered as an important factor in soliciting responses to the survey.

A total of 260 potential respondents were mailed the survey instrument in November 1984. A three week period was allowed for an initial response, at which time 165 responses had been received. A telephone follow-up procedure was begun after 4 weeks. This procedure coupled with the receipt of several residual questionnaires resulted in an overall return of 189 responses or approximately 73%. Of the 189 responses, a total of 84 were received from the academic sample (approximately 72%) and 105 were received from the industrial sample (approximately 74%).

METHOD OF ANALYSIS

The first purpose of the study was to identify from research, what skills or curricular experiences are needed to support the major needs of industrial computer graphics. This purpose was accomplished through the literature search and resulted in the development of the survey instrument.

The survey instrument is divided into 2 main parts. The first 6 items relate to basic graphics skills and concepts as well as computer graphics. Responses to these items indicate the importance and provision of basic skills in the curriculum and the overall importance and provision of computer graphics as a topic of study. The final 8 items on the questionnaire relate to importance and provision of specific computer skills and general types of hardware and software.

Responses to the survey instruments were compiled with the use of the university computing facility. Care was taken in the design of the survey instrument to facilitate the transfer of data to computer form. In order to determine the levels of importance and provision of the various skills and curricular experiences, an item analysis was performed. This analysis indicates the frequency of response for each item and item mean response for each group. These mean values are used throughout the analysis for indication of central tendency within each group, and to rank skills and experiences within groups. In addition to these statistics a ratio of importance was calculated for each skill. This ratio is of the following form

$$r = \frac{HI}{HWP}$$

where:

HI = mean value for "How Important"

HWP = mean value for "How Well Provided"

This ratio provides a level of overall importance in the curriculum, as seen by each group. In the data analysis, the "how important" factor is treated as an independent variable. The minimum r value possible is .200 represented by a mean importance level of 1.00 and a mean provision level of 5.00. The maximum r value possible is 5.00 represented by a mean importance level of 5.00 and a mean provision level of 1.00. It may then be suggested that a ratio value approaching 1.00 implies a balanced situation with regard to a particular skills importance and its provision in the curriculum. Values that depart from 1.00 (either higher or lower) imply an unbalanced situation and appropriate conclusions were made. An r value greater than 1.00 indicates that less provision has been applied to this skill or experience than its importance would indicate necessary. An r value less than 1.00 indicates that more provision has been applied to this skill or experience than its importance would indicate necessary.

Engineering education needs to provide the necessary skills and experiences so that graduates can perform at a level expected of them by industry. Therefore, the needs of industry are of great interest if our educational efforts are to be responsive to the changing needs of technology.

In order to determine if any differences exist between levels of importance and levels of provision within the two groups or between groups, a t-test for independent samples was performed on the item means. The Minitab statistics package on the university computer was used to perform the tests. The two-sample calculation was used in which no assumptions are made about the population variances. A level of $p < .05$ was required as a minimum for statistical significance of differences.

Four sets of t-tests were performed on the survey data. Set 1 indicates any signifance of differences between importance and provision of the given skills or experiences for the industrial sample. Set 2 indicates any significance of differences between importance and provision of the given skills or experiences for the academic sample. This data was used to determine if the respondents feel that a problem of emphasis exists with any particular skill or experience. Set 3 was performed on mean importance values between groups. This indicates the significance of differences between the importance level of a skill or experience as seen by industry and the importance of the same by academia. Set 4 indicates any significance of differences between the provision of the given skills or experiences as seen by each of the sample groups. This data was used to determine if any problems appear to exist in regard to the levels of provision for any skill or experience.

The final purpose of the study was to identify what types of hardware and software are being used to achieve curricular objectives in engineering graphics and what configurations appear to work well in an educational environment. The survey that was sent to the academic respondents contained a section where this data was solicited. In order to determine what types of hardware and software systems are being utilized, and an evaluation of them, an item analyses was performed on items 1, 3, 4 and 6. This analysis indicates frequency of response for each item, percent, and item mean response for the sample.

To determine if any of the hardware systems appear to function better than others in engineering graphics, a Crosstabulation of item 1 (hardware type) and item 3 (hardware appraisal) was performed. This table indicates the frequency of paired responses between the two items. To determine if any of the software systems appear to function better than others in engineering graphics, a crosstabulation of item 4 (software type) and item 6 (software appraisal) was performed. This table indicates the frequency of paired responses between the two items. Based upon the two crosstabulations, general conclusions were made about hardware and software use in engineering graphics education.

Items 2 and 5 solicit information on the names of the specific pieces of hardware and software being used. The responses to these items were listed and frequencies reported.

SUMMARY

The questionnaire instruments that were developed for this study were employed to determine if differences exist between industry and engineering schools on the subject of computer graphics in the engineering graphics curriculum. In addition, information was gathered about what various hardware and software are being utilized within the engineering graphics curriculum.

Two samples were selected randomly and a total of 260 potential respondents were mailed the survey instrument. A total of 189 responses (73%) were received. Of the 189 responses, a total of 84 were received from engineering schools (approximately 72% of their sample) and 105 were received from industry (approximately 74 % of their sample).

A series of t-tests were performed in order to determine if any significant differences between the samples exists. Frequency analysis and crosstabulations were used to determine what types of hardware and software are being used in engineering graphics, and what system(s) appear to work well in educational environments.

CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

Introduction

A total of 260 survey instruments were mailed to prospective respondents from industry and engineering schools. The industrial group contained a random sample of 142 members of the National Computer Graphics Association. Of this sample, 105 or 74% responded to the survey. The academic group (engineering schools) contained a random sample of 118 members of the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE). Of this sample, 84 or 72% responded to the survey. The total number of responses received from both samples was 189 or approximately 73% of the original mailing.

The data collected through the use of the survey instrument was analyzed and directed toward the following purposes.

1.) To determine the level of importance placed upon identified skills or curricular experiences by industry, and the level of provision these skills have received in engineering graduates.

2.) To determine the level of importance placed upon identified skills or curricular experiences by engineering schools and the level of provision for these skills that engineering students receive.

3.) To identify and describe any differences that exist between mean levels of importance and mean levels of provision of identified skills and experiences within the two groups.

4.) To identify and describe any differences that exist between mean levels of importance and mean levels of provision of identified skills and experiences between the two groups.

5.) To identify what types of hardware and software are being used to achieve curricular objectives in engineering graphics, and what configurations appear to work well in an educational environment.

The presentation of the data and findings includes an item analysis of the response by group. A ranking of the skills and experiences by group is also provided in accord with item mean responses for the Importance factor. The two halves of the questionnaire, Items 1-6 and Items 7-14, are ranked separately within each group.

A t-test for independent samples was performed on the data representing Importance and Provision levels for each skill or experience, within each of the two samples. In addition, this t-test was also performed on Importance and Provision levels between samples. Statistical significance of differences is reported for the .05 level and the .01 level of significance.

An item analysis was performed on part 2 of the Academic survey. The frequency of response is reported for items 1, 3, 4 and 6. Items 2 and 5 required that the academic respondents write in information about specific hardware and software type. This data is tabulated and frequencies reported where appropriate. A crosstabulation of Items 1 and 3 was performed indicating pairs of responses for hardware type and hardware appraisal. A crosstabulation of Items 4 and 6 was also performed indicating pairs of responses for software type and software appraisal.

RESULTS OF ITEM ANALYSES

Results of Item Analysis for the Industrial Survey

The first purpose of the data collection was to determine the level of importance placed upon identified skills or curricular experiences by industry, and the level of provision these skills have received in engineering graduates.

The survey instrument is divided into 2 parts. The first 6 items relate to basic graphics skills or areas of emphasis as well as computer graphics. The final 8 items on the survey relate to specific computer skills and general types of hardware and software. Responses to this survey are compiled in Table 1 and are in rank order by mean importance level.

The first 6 items on the instrument were all rated relatively high by industry. The highest mean importance value was 4.15, the average was 4.00 and lowest mean importance value was 3.87. In contrast to this, the corresponding mean provision values are relatively low. The highest mean provision value was 3.05, the average value was 2.56 and the lowest mean provision value was 2.14. Spatial visualization was ranked number 1 in importance by industry followed by sketching, combination of traditional graphics and computer graphics, traditional engineering graphics. The fact that these items are all ranked before computer graphics appears to indicate that traditional skills and concepts, or a combination of them, are important prerequisites to computer graphics experience. The topic of descriptive geometry was ranked last by industry on this portion of the survey. This may

Table 1
Item Analysis for the Industrial Survey
(Rank Ordered by Mean Importance)

	Rating Code HOW IMPORTANT (HI)						Rating Code HOW WELL PROVIDED (HWP)					
ITEM	1	2	3	4	5	(X)	1	2	3	4	5	(X)
Spatial Visualization	1	5	14	42	43	(4.15)	5	33	48	16	2	(2.77)
Sketching	1	5	16	48	35	(4.05)	22	48	28	5	2	(2.20)
Combination of Traditional Engineering Graphics and Computer Graphics	1	6	17	43	38	(4.05)	15	43	41	5	0	(2.34)
Traditional Engineering Graphics Abilities	.2	5	19	45	34	(3.99)	3	26	40	32	3	(3.05)
Computer Graphics	3	5	29	31	37	(3.89)	26	43	29	6	0	(2.14)
Descriptive Geometry	1	5	22	55	22	(3.87)	4	31	43	23	3	(2.90)
3-D Geometric Modeling	0	3	19	46	37	(4.11)	29	48	19	7	1	(2.06)
Problem Solving Analysis with CAD System on Graphics Designs	2	3	14	49	37	(4.10)	21	49	23	11	1	(2.25)
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	6	10	23	29	37	(3.77)	18	47	29	10	1	(2.32)
Computer-Aided Drafting	2	6	36	36	25	(3.72)	18	47	35	4	0	(2.24)
Experiences with CAD or CADD Using Microcomputer Systems	7	22	21	28	26	(3.42)	28	46	21	6	1	(2.07)
Experiences with CAD or CADD Using Mainframe Computers	6	16	30	35	18	(3.40)	24	40	30	8	1	(2.24)
Experiences with Commercial Turnkey CAD or CADD Hardware/Software	12	19	29	30	14	(3.14)	30	45	23	4	1	(2.03)
Computer Programming for Computer Graphics	17	36	35	16	1	(2.50)	21	14	32	23	15	(2.97)

be the result of descriptive geometry being integreted into the traditional engineering graphics courses instead of being a separate discipline.

The final 8 items on the survey are not rated on importance as consistantly high as the first 6 items. The highest mean value was 4.11, the average was 3.52 and the lowest mean importance value was 2.50. The provision values are also relatively low except for computer programming for computer graphics, where the mean provision value is greater than the mean importance value. Three dimensional geometric modeling was ranked number 1 by industry. This appears consistant with the number 1 ranking of spatial visualization on the first part of the survey, since the concepts are similar. However, problem solving with computer graphic tools was a very close second. Existing hardware and software "user" skills also ranks relatively high on this portion of the survey. This item ranks above computer-aided drafting, the three items regarding general types of computing systems, and far above computer programming for computer graphics. This appears to be a clear indication that learning to "use" computer graphics systems is more important than learning to program them. The individual types of hardware were ranked together (5, 6 and 7) by industry. Experiences with microcomputer systems was ranked higher than both mainframe computer systems and commerical turnkey systems. This ranking , although close, appears to indicate that industry is more interested in microcomputer and personal computer applications than mainframe or turnkey systems. Of curious interest is the lowest ranked skill, that of computer programming for computer graphics. Not only is it ranked far below the next closest item, but, it is the only item with an importance rating lower than the provision rating. This indicates that industry feels that more effort is going into this skill than is deserving.

All of the items on the survey (except computer programming) produced a greater importance than provision. The survey instrument may be responsible for producing these differences. Perhaps a feeling that conditions could always be better, coupled with the convenient side-by-side item rating layout were responsible for these differences.

The last reponse item on the industrial survey was an open item for any write-in "other" responses. The objective of this item was to solicit any important skills or experiences other than those listed. No importance or provision ratings were given by any of the respondents. The write-in responses that had an appropriate bearing on the survey are listed below:

1. Computer-aided engineering applications

2. data base concepts

3. data base software experiences

Results of Item Analysis for the Academic Survey

The second purpose of the data collection was to determine the level of importance placed upon identified skills or curricular experiences by engineering schools, and the level of provision for these skills that engineering students receive.

The survey instrument is divided into 2 parts. The first 6 items relate to basic graphics skills or areas of emphasis as well as computer graphics. The final 8 items on the survey relate to specific computer skills and general types of hardware and software. Responses to this survey are compiled in Table 2 and are in rank order by mean importance level.

The first 6 items on the instrument were all rated relatively high in importance by the academic respondents. The highest mean value of the 6 items was 4.39, the average was 3.91, and the lowest importance value was 3.07. In contrast to this, the corresponding mean provision values are relatively low. The highest mean value was 3.14, the average was 2.75 and the lowest was 2.42. Spatial visualization was ranked number 1 in

Table 2
Item Analysis for the Academic Survey
(Rank Ordered by Mean Importance)

ITEM	Rating Code HOW IMPORTANT (HI) 1	2	3	4	5	(X)	Rating Code HOW WELL PROVIDED (HWP) 1	2	3	4	5	(X)
Spatial Visualization	2	0	11	21	50	(4.39)	7	14	40	17	6	(3.01)
Combination of Traditional Engineering Graphics and Computer Graphics	1	2	11	34	36	(4.21)	11	30	30	12	1	(2.54)
Computer Graphics	1	2	14	41	26	(4.05)	16	27	32	7	2	(2.42)
Descriptive Geometry	1	6	15	41	21	(3.89)	13	26	27	10	8	(2.69)
Traditional Engineering Graphics Abilities	3	9	15	27	30	(3.85)	9	15	23	29	8	(3.14)
Sketching	8	19	22	29	6	(3.07)	10	24	35	9	6	(2.72)
Problem Solving Analysis with CAD System on Graphics Designs	3	7	18	32	24	(3.79)	26	22	27	7	2	(2.25)
Experiences with CAD or CADD Using Microcomputer Systems	4	10	19	33	18	(3.60)	23	24	22	10	4	(2.37)
Computer-Aided Drafting	2	9	26	33	14	(3.57)	17	28	30	5	4	(2.41)
Computer Programming for Computer Graphics	3	15	19	35	12	(3.45)	23	24	22	8	7	(2.42)
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3	12	29	27	13	(3.41)	15	25	30	10	4	(2.55)
Experiences with CAD or CADD Using Mainframe Computers	3	15	25	34	7	(3.32)	28	22	21	10	3	(2.26)
3-D Geometric Modeling	7	20	18	27	12	(3.20)	26	25	25	6	2	(2.20)
Experiences with Commercial Turnkey CAD or CADD Hardware/Software	12	19	24	24	5	(2.89)	39	21	13	10	1	(1.96)

importance by engineering schools followed by combination of traditional graphics and computer graphics, computer graphics, descriptive geometry, and traditional engineering graphics. Spatial visualization and the combination of traditional graphics and computer graphics both rank ahead of computer graphics. This indicates that the engineering respondents feel that some traditional skills (or at least a combination of skills) are necessary before, computer graphics. However, traditional engineering graphics abilities appear to be favored less than computer graphics. This could indicate an effort on the part of engineering schools to recognize the importance of new computerized tools for engineering graphics. The topic of sketching was ranked last by engineering schools on this portion of the survey.

The final 8 items on the instrument were not rated as consistantly high on importance as the first 6 items. The highest mean value was 3.79 as compared with 4.39 on the first 6 items. The average importance was 3.40 and the lowest importance was 2.89. However, 7 of the 8 items are rated above 3.00. The corresponding provision values are also relatively low. The highest mean provision value was only 2.55, the average value was 2.30 and the lowest provision value was 1.96. Problem solving analysis with CAD was ranked number 1 in importance by engineering schools as a skill that could be developed within engineering graphics curriculum. Engineering programs are, in general, more theory oriented in nature than technology or vocational programs. Engineering courses often focus on problem solving analysis, and the number 1 ranking here may be a reflection of that emphasis. Skills in computer-aided drafting and 3-D geometric modeling were ranked 3rd and 7th respectively. This ranking appears to represent an emphasis on the documentation of designs rather than on other skills. This may seem contrary to some of the rankings on the first 6 items. However sketching (ranked last on the first portion) and 3-D geometric modeling (ranked 7th of 8 on the second portion) are related in skill function and are ranked consistent with each other. Computer programming for computer graphics is ranked 4th and represents a reasonably high importance (3.45) for this skill. The literature supports the fact that computer programming has been one of the major techniques of teaching computer graphics in engineering schools. The reason it is not ranked higher may be that recent years have seen the development of many computer graphics systems that do not require the user to also be a programmer. However, the academic respondents still rank "user" skills behind programming skills. The general types of hardware and software are ranked 2nd, 6th and 8th. In that ranking, microcomputing systems appear most important followed by mainframe computing systems and commercial "turnkey" systems. The literature also supports the importance of microcomputers in academic institutions. Commercial systems remain to be extremely expensive for education. At the present time, only a relatively few number of engineering schools have been able to aquire this type of equipment. It may be possible that this monetary obstacle was responsible, in part, for the low ranking on the survey.

The results of the academic survey are important because it indicates what graphics skills or curricular experiences are important to engineering schools. Close examination of the item analysis for the academic survey, points to a partial casting aside of traditional skills in favor of new computerized ways. This is evident especially in the rankings of the first 6 items. Descriptive geometry, traditional engineering graphics and sketching are all rated lower than computer graphics or the combination response.

All of the items on the survey produced a greater mean importance value than provision value. The physical layout of the survey instrument may be responsible for producing these differences. Perhaps a feeling that things could always be better, coupled with the side-by-side item rating layout was responsible for these differences.

The last response item on the academic survey was an open item for any write-in "other" responses. The objective of this item was to solicit any skills or experiences other than those listed. Only three persons responded to this item with a write-in comment, however, only one was appropriate to the study. No importance or provision levels were given by the respondent. The comment was; Computer graphics problem solving of descriptive geometry problems.

ANALYSIS OF t-TEST RESULTS

The third purpose of this study was to identify and describe any differences that exist between mean levels of importance (How Important) and mean levels of provision (How Well Provided) within the two groups. A t-test for independent samples, making no assumptions of variances, was used to locate any differences. The t-values and level of significance is reported for each item in each group. An importance ratio is reported along with the first 2 tests. This ratio provides an overall feeling for the importance of a given skill or curricular experience.

Results of t-Test Between Importance and Provision for the Industrial Sample

The purpose of performing this test was to determine if the industrial respondents feel that a significant disparity exists between the level of a skills importance and its provision in engineering graduates. The results of these t-tests are compiled in Table 3, and items are in order of appearance on the survey instrument.

An initial examination of the r values shows that in all but one instance the r value is greater than 1.00. This indicates that there has been generally less provision for these skills or experiences than their individual importance levels would indicate is necessary. The skill of computer programming for computer graphics produced an r value of .84, and was the only item on the industrial survey with a value less than 1.00. This indicates that a reverse situation exists as compared to other items. The industrial respondents feel that more effort is given to computer programming than its individual importance level (2.50) would indicate is necessary. The highest r value reported on the items was 1.99 and the lowest r value reported was (.840).

To determine if the r values represent a significant departure from 1.00 (balance), a t-test for independent samples was performed. The t-values values are reported in the last column of Table 3 and their significance level is reported with asterisks. As the t values indicate, each of the 14 survey items produced a satistically

Table 3
Results of t-test
Between Importance and Provision for the
Industrial Sample

ITEM	HI_I	HWP_I	r	t
Traditional Engineering Graphics Abilities	3.99	3.05	1.30	7.38**
Spatial Visualization	4.15	2.77	1.49	11.46**
Descriptive Geometry	3.87	2.90	1.33	8.18**
Sketching	4.05	2.20	1.83	15.12**
Computer Graphics	3.89	2.14	1.81	13.26**
Combination of Traditional Engineering Graphics and Computer Graphics	4.05	2.34	1.72	14.48**
3-D Geometric Modeling	4.11	2.06	1.99	17.30**
Computer-Aided Drafting	3.72	2.24	1.66	12.28**
Computer Programming for Computer Graphics	2.50	2.97	.84	-2.91**
Problem Solving Analysis with CAD System on Graphic Designs	4.10	2.25	1.81	14.81**
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.77	2.32	1.62	9.90**
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	3.14	2.03	1.54	7.54**
Experience with CAD or CADD Using Microcomputer Systems	3.42	2.07	1.64	8.83**
Experiences with CAD or CADD Using Mainframe Computer Systems	3.40	2.24	1.52	8.18**

HI_I – How Important within the Industrial Sample

HWP_I – How Well Provided within the Industrial Sample

* – Significant at the .05 level

** – Significant at the .01 level

$$r = \frac{HI_I}{HWP_I}$$

significant difference. The .01 level of significance is the highest level reported. Except for the instance of one item, all of the skills have significantly higher importance levels than provision levels. This indicates that the industrial respondents feel that more effort should go into providing for all of these skills, except for computer programming for computer graphics. How this great disparity occurred may be open to some speculation, but, it is proposed that the greatest portion of these differences were a function of the survey instrument itself. However, it is important to note that the industrial respondents felt strongly in a reverse sense about the computer programming item than they did about all the others. It is also important to note that a low importance level does not indicate no importance. From this test it can be concluded that the industrial respondents feel that most of the skills or experiences listed could benefit from greater emphasis in the academic curriculum. In addition, they feel that skills in computer programming for computer graphics is receiving too much attention in the academic curriculum. Fifty percent of the repondents rated this skill 2 or less on importance, and 66 % of them rated this skill 3 or higher in provision.

Results of t-Test Between Importance and Provision for the Academic Sample

The purpose of performing this test was to determine if engineering school respondents feel that a significant disparity exists between the level of a skills importance and its provision in the curriculum. The results of these t-tests are compiled in Table 4, and items are in order of appearance on the survey instrument.

An examination of the importance ratios (r) shows that all of the values are greater than 1.00. A ratio of 1.00 indicates that a balance exists between the two factors. In general, the values over 1.00 indicate that less provision has been allowed in the curriculum for these skills or experiences, than their importance levels would indicate is necessary.

To determine if the r values represent a significant departure from 1.00 (balance), a t-test for independent samples was performed. The t-values are reported in the last column of Table 4 and their significance level is indicated with asterisks. As the t-values indicate, each of the 14 survey items produced a statistically significant difference. The .01 level of significance is the highest level reported. All of the skills or experiences have significantly higher importance levels

Table 4
Results of t-test
Between Importance and Provision for the
Academic Sample

ITEM	HI_A	HWP_A	r	t
Traditional Engineering Graphics Abilities	3.85	3.14	1.22	4.05**
Spatial Visualization	4.39	3.01	1.45	9.44**
Descriptive Geometry	3.89	2.69	1.44	7.48**
Sketching	3.07	2.72	1.12	2.06*
Computer Graphics	4.05	2.42	1.67	11.70**
Combination of Traditional Engineering Graphics and Computer Graphics	4.21	2.54	1.65	12.06**
3-D Geometric Modeling	3.20	2.20	1.45	5.77**
Computer-Aided Drafting	3.57	2.41	1.47	7.46**
Computer Programming for Computer Graphics	3.45	2.42	1.42	5.79**
Problem Solving Analysis with CAD System on Graphic Designs	3.79	2.25	1.68	9.44**
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.41	2.55	1.33	5.28**
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	2.89	1.96	1.47	5.33**
Experience with CAD or CADD Using Microcomputer Systems	3.60	2.37	1.51	7.07**
Experiences with CAD or CADD Using Mainframe Computer Systems	3.32	2.26	1.46	6.40**

HI_A - How Important within the Academic Sample

HWP_A - How Well Provided within the Academic Sample

* - Significant at the .05 level

** - Significant at the .01 level

$$r = \frac{HI_A}{HWP_A}$$

than provision levels, and their respective importance ratios represent a significant departure from 1.00 or from a balanced situation. This indicates that the engineering school respondents feel that more effort should go into providing for all of these skills in the curriculum. How this number of differences occurred, may be (as explained earlier) open to some speculation. However, it is proposed that the greatest portion of these differences were a function of the instrumentation itself.

Results of the Importance Factor t-Test Between Samples

In order to compare and contrast the importance levels of the two groups, a third t-test was performed on the mean importance levels between groups. This statistical test provides an insight into how responsive engineering schools are to the items industry feels are important. The results of this test are compiled in Table 5, and items are in order of appearance on the survey instrument. The t-values are reported in the last column of Table 5 and their significance level in indicated with asterisks.

The first 6 items on the instrument relate to basic graphics skills or areas of emphasis. Examination of the t-values on this portion of the instrument shows that only the skill of sketching produced a statistically

Table 5
Results of t-test
Importance (HI_A) vs Importance (HI_I)
Between Samples

ITEM	HI_A	HI_I	t
Traditional Engineering Graphics Abilities	3.85	3.99	.86
Spatial Visualization	4.39	4.15	1.83
Descriptive Geometry	3.89	3.87	.13
Sketching	3.07	4.05	6.62**
Computer Graphics	4.05	3.89	1.12
Combination of Traditional Engineering Graphics and Computer Graphics	4.21	4.05	1.21
3-D Geometric Modeling	3.20	4.11	5.98**
Computer-Aided Drafting	3.57	3.72	1.07
Computer Programming for Computer Graphics	3.45	2.50	6.34**
Problem Solving Analysis with CAD System on Graphic Designs	3.79	4.10	2.13*
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	3.41	3.77	2.18*
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	2.89	3.14	1.45
Experience with CAD or CADD Using Microcomputer Systems	3.60	3.42	1.07
Experiences with CAD or CADD Using Mainframe Computer Systems	3.32	3.40	.57

HI_I - How Important within the Industrial Sample

HI_A - How Important within the Academic Sample

* - Significant at the .05 level
** - Significant at the .01 level

significant difference. This difference indicates that industry and engineering schools disagree on the importance level of this skill. Industry places significantly more importance on this skill than engineering schools. This is also consistant with the earlier rank ordering. Industry ranks sketching 2nd among the first 6 items and engineering schools rank it 6th or last among the same items. The remaining 5 items of the first 6, did not produce any significant t-values. It may then be concluded that industry and engineering schools are part of the same population sample in regard to these skills.

The final 8 items on the instrument relate to specific computer skills and general types of hardware and software. Examination of the t-values indicates that 4 items are statistically significant; geometric modeling, computer programming, problem solving, and "user" skills. Three dimensional geometric modeling was significant at the .01 level. Industry places significantly more importance on this skill than engineering schools. Industry ranked geometric modeling 1st out of the final 8 items, and engineering schools ranked this skill 7th. Computer programming for computer graphics was also significant at the .01 level. In regard to this skill there is a reverse direction of significance. Engineering schools place significantly more importance on this skill than industry. Engineering schools ranked computer programming for computer graphics 4th out of 8 items and industry ranked this skill last. Computer programming has been a convenient vehicle for many schools as a way of getting into computer graphics. Industry, however seems to be pointing out that computer programming has been receiving too much emphasis in the curriculum. Based on the results of this item, it would appear that engineering schools feel computer programming for computer graphics is important enough to deserve expansion in the curriculum.

Problem solving analysis with CAD systems produced a significant difference at the .05 level. Industry places significantly more importance on this skill than engineering schools. However, it is important to note that the individual samples ranked this skill in a very similar manner. Industry ranked this skill 2nd among the final 8 items and engineering schools ranked this 1st on these items. Existing hardware/software "user" skills was also significant at the .05 level. Again, industry places significantly more importance on these "user" skills than engineering schools. Industry ranks these skills 3rd out of the final 8, and engineering schools ranks them 5th. One possible explanation for the difference is that engineering schools are teaching more programming skills (non-user skills) than any others. Industry on the other hand has been able to move ahead to more use of interactive systems that do not require programming skills.

In addition to significant differences on this test, it is also of interest to point out ones that were not significant. In regard to instruction in basic engineering graphics, industry and engineering schools are in agreement as to its importance, and their respective rankings are similar. Computer graphics as a topic of study is ranked more important to engineering schools than it is to industry. However, the two samples both rank the combination of computer graphics and traditional graphics ahead of both computer graphics, and traditional engineering graphics.

Results of the Provision Factor t-Test Between Samples

In order to compare and contrast the levels of provision (How Well Provided), a fourth t-test was performed on the mean provision levels between samples. This statistical test provides some insight into each samples feelings as to the provision for these skills or experiences in the curriculum. The results of this test are compiled in Table 6, and items are in order of appearance on the survey instrument.

In regard to the first 6 items, only two items

Table 6
Results of t-test
Provision (HWP_A) vs Provision (HWP_I)
Between Samples

ITEM	HWP_A	HWP_I	t
Traditional Engineering Graphics Abilities	3.14	3.05	.55
Spatial Visualization	3.01	2.77	1.70
Descriptive Geometry	2.69	2.90	1.38
Sketching	2.72	2.20	3.59**
Computer Graphics	2.42	2.14	2.09*
Combination of Traditional Engineering Graphics and Computer Graphics	2.54	2.34	1.57
3-D Geometric Modeling	2.20	2.06	.93
Computer-Aided Drafting	2.41	2.24	1.29
Computer Programming for Computer Graphics	2.42	2.97	2.92**
Problem Solving Analysis with CAD System on Graphic Designs	2.25	2.25	.04
Existing Hardware/Software "User" Skills (Mechanics of Using a System)	2.55	2.32	1.61
Experience with Commercial Turnkey CAD or CADD System Hardware/Software	1.96	2.03	.50
Experience with CAD or CADD Using Microcomputer Systems	2.37	2.07	1.90*
Experiences with CAD or CADD Using Mainframe Computer Systems	2.36	2.24	.12

HWP_A - How Well Provided in Academic Sample

HWP_I - How Well Provided the Industrial Sample

* - Significant at the .05 level
** - Significant at the .01 level

produced a statistically significant difference between provision levels. Sketching was significant at the .01 level. Engineering schools feel that this skill is provided for significantly more than industry does. This indicates that industry feels that engineering schools could be developing this skill to a greater degree. It is important to note that this item test is also matched by a significant difference between mean importance levels between samples. Computer graphics was significant at the .05 level. This also indicates that engineering shools could do more to develop this skill or experience. However, it is important to note that the "combination" item was ranked higher by both groups than computer graphics.

Among the final 8 items, computer programming for computer graphics was significant at the .01 level. Industry feels that this skill is being provided significantly more than engineering schools do. Industry also feels (as indicated in earlier analysis) that computer programming is not as important as engineering schools feel it is. Experience with microcomputer systems was just barely significant at the .05 level. In regard to this item, industry feels that microcomputer experience with CAD is not being provided as well as engineering schools believe it is. However, it is also important to see that both provision levels, 2.37 and 2.07 are relatively low.

Analysis of the Hardware and Software Items for the Academic Sample

The final purpose of the study was to identify what types of hardware and software are being used to achieve curricular objectives in engineering graphics, and what configurations appear to work well in an educational environment.

In order to determine what general types of hardware systems are being utilized, an item analysis was performed on item 1. The item requested responders to circle the type of hardware system they utilize to achieve their objectives in engineering graphics. In addition to mainframe computers, microcomputers, batch, and turnkey systems, a "none" response was also included. Responders were requested to circle "none" if their students do not study computer graphics. Table 7 shows the absolute frequency and percent for each response to the item. The largest portion of the respondents (52.4%) indicated that they are utilizing microcomputer hardware systems followed by 29.8% who utilize mainframe computer systems. Only 3 of the 84 respondents are using turnkey systems (commercial), and only 1 respondent indicated that their students use a batch mode to do graphics. Of particular interest is the 11 respondents who circled "none". This indicates that 13.1% of the respondents do not have

Table 7
Frequency of Responses - Item 1
"Hardware Type"

	Mainframe Computer	Micro-Computer	Batch	Turnkey System	None
Frequency	25	44	1	3	11
Percent	29.8%	52.4%	1.2%	3.6%	13.1%

N = 84

Table 8
Frequency of Responses - Item 3
"Hardware Appraisal"

	(1) Poor	(2) Fair	(3) Good	(4) Very Good	(5) Excellent	(X)
Frequency	0	13	25	24	11	(3.45)
Percent	0	17.8%	34.3%	32.9%	15.0%	

N = 73*

* respondents who indicate "none" on item 1 do not rate hardware.

students utilizing computerized methods in engineering graphics.

In order to gain insight into how well the respondents feel their individual hardware functions, they were asked for a personal appraisal. Items used a scale including; poor, fair, good, very good, and excellent. Respondents who indicated "none" for hardware system used, did not appraise the hardware. An item analysis was performed on this data and the results are found in Table 8. Of initial interest is that no one indicated that their hardware was "poor". On the other hand 11 respondents or 15% indicated that their hardware was "excellent". The largest frequency was 25 and indicated that 34.3% of the respondents feel their hardware is "good". If this is placed together with those who circled "very good" it can be concluded that 67.2% of the respondents rate their hardware as "good" or "very good". On the five point scale, the average rating was then 3.45 or approximately midway between marks.

To determine if any of the hardware systems utilized appear to function better than others in engineering graphics, a crosstabultation of Item 1 (hardware type) and Item 3 (hardware appraisal) was performed. The results of this crosstabulation are shown in Table 9. Twenty five of the 84 respondents indicated that they utilize mainframe

TABLE 9

Crosstabulation of Hardware Type by Hardware Appraisal

Count / Row PCT / Col PCT / Tot PCT		Poor 1	Fair 2	Good 3	Very Good 4	Excell 5	N/R*	Row Total
Hardware Type								
Mainframe	1	0 0.00 0.00 0.00	1 4.00 7.69 1.19	8 32.00 32.00 9.54	11 44.00 45.83 13.09	5 20.00 45.45 5.95	0 0.00 0.00 0.00	25 29.77
Micro-computer	2	0 0.00 0.00 0.00	11 25.00 84.61 13.09	16 36.36 64.00 19.04	11 25.00 45.83 13.09	6 13.64 54.54 7.14	0 0.00 0.00 0.00	44 52.38
Batch	3	0 0.00 0.00 0.00	1 100.00 7.69 1.19	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 1.19
Turnkey	4	0 0.00 0.00 0.00	0 0.00 0.00 0.00	1 33.33 4.00 1.19	2 66.67 8.33 2.38	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 3.57
None	5	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	11 100.00 100.00 13.09	11 13.09
Column Total		0 0.00	13 15.48	25 29.77	24 28.57	11 13.09	11 13.09	84 100.00

* No Rating

computers. Of this 25, no one rated them "poor" and ony 1 rated them "fair". The largest frequency for this response (11 or 44%) was in the "very good" category. In general, the academic respondents express positive feelings about the utilization of mainframe computer systems even though only approximately 30% utilize them. The greatest frequency of response to Item 1 was in the microcomputer category with over 52% of the responses. Of this total, no one rated them "poor", but 11 or 25% indicated that their microcomputer systems were "fair", unlike for mainframes. The fact that microcomputers are; many, small, personal, affordable and relatively easy to operate, may also have contributed to a higher level of criticism than mainframes. The largest number of respondents circled "good" for microcomputers, in contrast to "very good" for mainframes. The mainframe and microcomputer responses amounted to 82% of the total number of responses for the items. The single batch response rated that system "fair" and only 3 turnkey responses, 1 - "good" and 2 - "very good" are noted. From the results of this crosstabulation it can be concluded that mainframe and microcomputer systems are by far used the most. The average rating for microcomputers (3.27) is lower than for mainframes (3.80). The large number of microcomputer systems being utilized is also an indication of the direction of equipment aquisitions for engineering graphics. The low number of respondents rating turnkey systems, even though their ratings were generally very good, is an indication of the expensive nature of these systems. The average rating (3.66) for turnkey systems is extremely similar to mainframe and microcomputers however.

In order to determine what general types of software are being utilized an item analysis was performed on Item 4. The item requested respondents to circle the type of software system they utilize to achieve their objectives in engineering graphics. In addition to in-house written, commercial vender, user group, and other, a "none" response was also included. Respondents were requested to circle "none" if their students fo not study computer graphics. Table 10 indicates the absolute frequency and percent for each response. The largest portion of the respondents (60.7%) indicated that they are using software procured from a commercial vender. This is not surprising since there is a large amount of software on the market for all types of computing systems, at all price levels. The quantity of commercial software available has also increased greatly in recent years, particularly in the area of microcomputer systems. The second largest response for this item was 22.6% for "in-house" written software, or software written by personnel at that institution. This frequency can be contrasted to a survey cited in the literature where it was reported that 2/3 of

Table 10
Frequency of Responses - Item 4
"Software Type"

	In House	Commercial Vender	User Group	Other	None
Frequency	19	51	3	0	11
Percent	22.6%	60.7%	3.6%	0	13.1%

N = 84

Table 11
Frequency of Responses - Item 6
"Software Appraisal"

	(1) Poor	(2) Fair	(3) Good	(3) Very Good	(5) Excellent	(X)
Frequency	2	16	23	25	7	(3.26)
Percent	2.7%	21.9%	31.5%	34.2%	9.6%	

N = 73*

* respondents who indicate "none" on item 4 do not rate software.

the instructional computer graphics software was being developed by teaching faculty. This 1982 survey by the Engineering Design Graphics Division of ASEE was, however, slightly broader in base since it requested information about computer graphics software in general. The present study was narrower, soliciting information regarding computer graphics software for engineering graphics. This contrast may account for the large difference in numbers or it may be that there is significantly more commercial software available since 1982. Only 3 or 3.6% of the respondent indicated that their software for engineering graphics came from a user group. The reason for this may be that the number of user groups is few or that these groups are not generally providing software for engineering graphics. Again, as with the hardware items, 11 or 13.1% circled "none". This indicates that the respondents do not have students utilizing computerized methods in engineering graphics.

In order to gain insight into how well the respondents feel their individual hardware functions, they were asked in Item 6 for a personal appraisal. This item used a scale including; poor, fair, good, very good, and excellent. Respondents who indicated "none" for software type in Item 4, did not appraise the software. An item analysis was performed on this data and results are found in Table 11. Unlike the hardware appraisal, this item received marks on all 5 scale ratings from poor to excellent. The largest frequencies of response were in the "good" and "very good" category with 65.7% of all responses. The item mean was 3.26. Almost 25% of the respondents however rate their software in the "poor" to "fair" category.

To determine if any of the software systems utilized appear to function better than others in engineering graphics, a crosstabulation of item 4 (software type) and item 6 (software appraisal) was performed. The results of this crosstabulation are found in Table 12. Of the 19 responses for in-house software, no one rated them "poor" or "excellent". The average response was 3.05 or "good". In-house written software is usally written to perform specific tasks outlined by an instructor. They therefore are performing well on the average but there are no indications of extreme feelings either way. The largest frequency response was in the category of commercial vender software. The 51 responses are spread across the entire rating scale. The average rating, however, was 3.35 and somewhat larger than the in-house average. Commercial software is usually written for consumption among the largest population possible. If the given software does not meet the individuals needs it may not be appraised highly. The large quantities of commercial software that are available to comsumers also produces a

TABLE 12

Crosstabulation of Software Type by Software Appraisal

Count Row PCT Col PCT Tot PCT		Software Appraisal Poor 1	Fair 2	Good 3	Very Good 4	Excell 5	N/R*	Row Total
Software Type								
In House	1	0 0.00 0.00 0.00	5 26.31 31.25 5.95	8 42.10 36.36 9.52	6 31.57 23.07 7.14	0 0.00 0.00 0.00	0 0.00 0.00 0.00	19 22.62
Comm Vend	2	2 39.21 100.00 2.38	10 19.60 62.50 11.90	14 27.45 63.64 16.66	18 35.29 69.23 21.42	7 13.72 100.00 8.33	0 0.00 0.00 0.00	51 60.72
User Group	3	0 0.00 0.00 0.00	1 33.33 6.25 1.19	0 0.00 0.00 0.00	2 66.67 7.69 2.38	0 0.00 0.00 0.00	0 0.00 0.00 0.00	3 3.57
Other	4	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00
None	5	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	0 0.00 0.00 0.00	11 100.00 100.00 13.09	11 13.09
Column Total		2 2.38	16 19.05	22 26.20	26 30.95	7 8.33	11 13.09	84 100.00

* No rating

wider quality range and this frequency range may reflect that experience. The only other response was for user group software. However 2 of the 3 responses were in the "very good" category, which indicates that the software received from user groups was on the average a good to very good quality.

Items 2 and 5 on this portion of the survey solicited write-in information on specific hardware and software systems being used. Fifty eight responses were received for Item 2 in regard to specific hardware type. Sixty responses were received for Item 5 in regard to specific software systems used. Of the total number of surveys received, only about 70% offered information to these items.

Item 2 asked the respondents to name the specific hardware system being used to achieve objectives in engineering graphics. Respondents replied in 3 areas; that of mainframe computers, microcomputers and turnkey systems. The following list indicates the names of the hardware and the number of citations from the surveys.

MICROCOMPUTERS	
TEK 4052	1
TEK 4054	1
IBM PC	13
IBM AT	1
IBM XT	1
Apple II	5
Apple IIe	1
Apple IIc	1
Terak	4
HP 2647A	1
DEC GIGI	1
Commodore	1
HP 1000	1
North Star	1

MAINFRAME COMPUTERS	
VAX 11/780	8
VAX 11/750	3
Prime	3
IBM 3081D	1
Amdahl	1
IBM 4381	1
PDP 11/35	1
PDP 11/44	1

TURNKEY SYSTEMS	
Computerivision	2
Applicon	1
Bruning CAD	1
GE CALMA	1

The greatest number of citations in the mainframe category was for VAX computing systems. Eleven of the 20 mainframe responses were for these computers. The greatest number of microcomputer citations was for the IBM personal computer with 13 citations. Commercial turnkey systems were used by 5 respondents. One of the respondents indicated use of 3 of these systems in their institutions. Item 5 asked the respondents to name the specific software system used to achieve objectives in engineering graphics. Respondents also replied here in 3 areas, that of in-house written, commercial venders, and user groups. The following list indicates the names of the software and the number of citations from the surveys.

IN-HOUSE WRITTEN

SPACEVU	1
PADDLE I	1
GRAFIX	1
GATRAN	1
INTEGRAL	1
FAS 40	1
SYS PLOT	1
CAG	1

COMMERCIAL VENDERS

ACAD	1	CADAPPLE	4
FAST DRAFT	1	CD 2000	1
MATC CAD	3	CAD AM	2
DI 3000	2	AUTO CAD	3
MINN DRAFT	4	PC CAD	5
ANVIL 4000	1	CAD KEY	1
PLOT 10	2	GEO MOD	1
FUN PLOT	1	AUTO PLOT	1
VERSA CAD	1	ICS	1
CASCADE	1	PAGE 1000	1
MOVIE B.Y.U.	5	HOLGUN-CEADS	1
ADV SPACE GRAPHICS	1	AD 2000	1
ENER GRAPHICS	1	EUCLID	1
MICRO CAD	1	TEKNICAD	1
MINICAD	1		

USER GROUPS

MAPT	1
PC PG	1

The high number of commercial vender software listed is evidence that commercial sources are becoming more. These commercial sources have been increasingly responsive to the needs in engineering graphics, and engineering in general. In-house written software were listed by 8 respondents, but are few by comparison to commercial sources. User groups apparently supply very little software for engineering graphics as indicated by only 2 responses.

Items 2 and 5 provide little additional information other than that there is a large quantity of different types of hardware and software being used in engineering graphics. The frequency of a given citation gives some insight into relative polularity of an item but no real evaluation. More microcomputer systems are used than mainframes and IBM personal computer systems appear to stand out as being most popular. In mainframe systems, the VAX computers appear to be used more than any other. In the area of software, commercial venders provide the vast majority of the software utilized. Several software appear in multiples but no one version or name stands out above others. In-house written software is used in a minority of institutions. In all likelihood this software lends itself to operation in only one or few locations.

CHAPTER V

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Introduction

The major purpose of this study was to evaluate the state of the curriculum in engineering graphics, specifically, the impact of computer graphics on instruction in engineering graphics. Computers have advanced to a point where they are less expensive than ever before, and are being used in all areas of education, courses in engineering graphics have not been exempt from this advancing technology. With the advent of computer graphics, the curriculum in engineering graphics is beginning to take on a new shape. Just what this new shape should be, is a major question. If engineering schools provide the workforce of engineers in industry, then the curriculum must reflect the needs of industry. This study focused on what the needs of industry are in the area of computer graphics, how important these needs are, and how well these needs are being provided for.

To begin determining these needs, a literature search was performed. This search identified from research, what skills or curricular experiences are needed by engineers. The data from this literature search was used to construct a survey instrument. The resulting instrument was mailed to a random sample of 142 industrial respondents. To compare and contrast these identified needs with the current curriculum, the instrument was also mailed to a random sample of 118 engineering schools. This survey also asked respondents about what computer hardware and software were being used to achieve objectives in engineering graphics. A total of 189 or approximately 73% of the surveys were returned. An item analysis was performed on each sample survey and a ratio of importance was calculated for each item. A t-test for independent samples was used to determine significant differences within and between groups.

Disscussion of the Industrial Survey

The first purpose of the study was to identify from research, what skills or curricular experiences are needed to support the major needs of industrial computer graphics technology. The literature exposes several skills that industry feels are necessary in engineering graduates. After analyzing the literature, the following list was established:

3-D Geometric modeling

Computer-aided drafting

Computer programming for computer graphics

Probelm solving analysis with CAD

Existing hardware and software "user" skills

Experiences with Commercial CAD system

Traditional engineering graphics

Sketching

Spatial visualization

Descriptive geometry

These above skills and experiences were used as a basis for construction of the survey instrument. From the literature review, it is concluded that all of these skills and experiences identified are important elements of the skill base of engineers in industry. In order to complete, or round out this list, four items were added:

Computer graphics

Experiences with CAD using microcomputers systems

Experiences with CAD using mainframe computer systems

Combination of computer graphics and traditional engineering graphics

The second purpose of the study was to determine the level of importance placed on identified skills of curricular experiences by industry and the level of provision these skills and expiences have received in engineering graduates.

From an initial analysis of the survey responses, it can be concluded that all of the skills, as identified in the literature, are important elements of the skill base of enginers in industry. This is evidenced by the magnitude of the important levels and the lack of response to the "other" category. If the industrial respondents had felt that skills other than those listed were more important, they in all liklihood would have indicated so by the importance levels and the "other" category.

The first 6 items on the survey provide a picture of the relationship of basic graphics skills to computerized methods. Spatial visualization was ranked 1st by the industrial respondents. Sharing the 2.5 rank are sketching and the combination of traditional engineering graphics and computer graphics, with an average importance level of 4.05. Four of the 6 items on this portions of the survey rank ahead of computer graphics by itself, even the "combination" item. Industry apparently feels that these skills are important before computer graphics. Discriptive geometry was ranked 6th out of 6 items, but this an importance level of 3.87 it is still an important item. The final 8 items on the survey represent specific computer skills and general types of hardware and software experiences. From the ranking of this list it can be concluded that computer skills and experiences in graphics are generally important. However, one skill ranks significantly lower than all the rest, that of computer programming for computer graphics. Three dimensional geometric modeling and spatial visualization both rank 1st on their respective parts of the survey, and are similar in concept. Existing hardware and software "user" skills ranks above computer-aided drafting, the three items regarding hardware systems, and far above computer programming for computer graphics. This appears to be an indication that learning to "use" computer graphics is more important than learning to program one. In regard to the general types of CAD equipment, the importance levels indicate that students should have experience with all three. But microcomputer systems appear to be receiving more attention in industry.

The "How Well Provided" responses to the survey, provide a picture of how well industry feels the skills and experiences are being provided for. These levels all represent significant differences from their respective importance levels. Ordinarily this result would indicate a conclusion that all of the skill and experience items require improvement of some sort. In fact, the importance ratios would indicate that, in all but one instance, there needs to be more provision for each of these items in the curriculum. However, it would not seem fair to single out the educational system as a general problem area, rather, that the survey instrument produced these differences.

The survey, beyond the importance rankings, may simply indicate that there is always room for improvement in educational systems. The importance ratios provide a sence of direction for improvement in the curriculum. Almost all items have ratio greater than 1.00, indicating a need for more provision of this skill ore experience. However, in the examination of these ratios, one stands out different from the rest. With an importance ratio of .84 (less than 1.00 or balance) it can be concluded that industry feels that this skill is being provided for more than necessary. It is important to note that this is not a conclusion that computer programming is, in itself unimportant.

Summary of Conclusions Based on the Industrial Survey

Based on the analysis an discussion of the industrial survey, the following conclusions were drawn:

1. All of the skills and curricular experiences, as identified in the literature and as added, are important to engineers and the engineering graphics curriculum. Therefore the survey items have content validity.

2. Existing hardware and software "user" skills are more important than computer programming skills.

3. Computer-aided drafting is important to the engineering graphics curriculum, even though it may not be a formal part of the students evential job description as an engineer.

4. Microcomputer and mainframe computer system experience appears to be more important than experience with commercial turnkey systems.

Discussion of the Academic Survey

The third purpose of the study was to determine the level of importance placed on identified skills or curricular experiences by engineering schools and the level of provision for these skills that engineering students receive.

From an initial analysis of the responses, it can be concluded that the academic respondents considered all of the survey items as generally important. This is evidenced by the magnitude of the importance levels and the lack of response to the "other" category. If the academic respondents had felt that skills or experiences other than those listed were more important, they in all liklihood, would have indicated so by the importance levels and write-in responses to the "other" category.

The first 6 items on the survey provide a picture of the relationship of basic graphics skills to computerized methods. Only one skill (spatial visualization) is ranked ahead of computerized or partially computerized approaches to graphics. The fact that the "combination" item ranked 2nd and ahead of computer graphics, however, indicates that some manual or traditional skills are desired. But traditional engineering graphics is favored less than computer approaches. This ranking leads to a general conclusion that engineering schools are recognizing the importance of new computerized technology. Sketching as a manual skill ranks significantly lower than all other skills on this portion of the survey. The final 8 items on the survey represent specific computer skills and general types of hardware and software experiences. Probelm solving analysis is ranked 1st by engineering schools on this portion of the survey. Engineering programs in genral focus on problem solving and analysis, and this ranking may be a reflection of that emphasis. Computer programming for computer graphics is ranked 4th, and appears to be relatively important to engineering schools. Nearly sharing this rank however is existing hardware and software "user" skills. This may seem contradictory at first but it may be a indication that more "user" oriented software is being integrated into engineering graphics programs. Three dimensional geometric modeling was ranked 7th out of 8 items and is consistant with the low ranking of sketching in the first 6 items of the survey, since the two items are similar. In regard to experiences with general types of CAD equipment, the importance ratios indicate that microcomputer systems are most important followed by mainframe systems. Commercial turnkey CAD system experience was the only item on the survey that indicated an importance level below 3.00.

The "How Well Provided" reponses to the survey provide a picture of how well engineering schools feel they are providing for these skills and experiences. These levels all represent significant differences from their respective importance levels. The importance ratios, which are all greater than 1.00 would indicate that all of the skills and experiences need improvement in provision. However, it is suggested that the survey instrument produced these significant differences. The survey, beyond the importance rankings may simply indicate that there is always room for improvement in the educational system.

Summary of Conclusions Based on the Academic Survey

Based on the analysis and discussion of the academic survey, the following conclusions were drawn:

1. All of the skills and curricular experiences, as identified in the literature, and as added, are important to engineers and the engineering graphics curriculum. Therefore, the survey items have content validity.

2. Traditional engineering graphics is favored less than computerized approaches to graphics.

3. Sketching as a skill is ranked significantly lower than most other skills.

4. Microcomputer and mainframe computer system experience appears to be more important than experience with commercial turnkey systems.

5. Computer-aided drafting is important to the engineering graphics curriculum, even though it may not be a formal part of the students eventual job description as an engineer.

6. Computer programming for computer graphics, and existing hardware and software "user" skills are both important, and are regarded almost equally.

7. Engineering schools are actively pursuing implementation of computer graphics into the

engineering graphics curriculum.

Comparison of the Two Surveys

The fourth purpose of the study was to identify and describe any differences that exist between mean levels of importance and mean levels of provision within the two groups and between groups. This section will discuss differences of importance and provision levels between the two groups only and will also include a comparison of rankings.

A comparison of the item rankings of the two samples shows that the two groups actually rank the items quite similar. Strong differences occur in relatively few places. On the first 6 items, ranks are similar except that where industry ranks sketching 2nd, engineering schools rank this skill 6th or last. In general, industry ranks more skills ahead of computer graphics than engineering schools, and both groups rank the "combination" alternative ahead of computer graphics. On the final 8 items, ranking was less similar. Geometric modeling was ranked 1st by industry, but 7th by engineering schools. Computer programming for computer graphics was ranked 8th (last) by industry but 4th by engineering schools. Existing hardware and software "user" skills was ranked 3rd by industry and 5th by engineering schools.

To determine how responsive engineering schools are to the items that industry feels are important, a t-test for independent samples was performed. Because the rankings on the survey items were generally similar, this test also performs the function of identifying those items that are ranked close enough to be considered the same ranking, and identifying those that clearly represent different rankings. Although some rankings are quite different between samples, industry and engineering schools are in agreement on the importance levels of 9 out of 14 items. Significant differences occur for the following items:

1. Sketching
2. 3-D Geometric modeling
3. Problem solving analysis with CAD systems
4. Existing hardware and software "user" skills.

Industry places significantly more importance on these items than engineering schools. A significant difference also exists in computer programming for computer graphics. Industry places significantly less importance on this skill than do engineering schools.

In order to contrast the levels of provision (How Well Provided) between samples, a t-test for independent samples was performed. This test performs the function of identifying items that have provision levels close enough together so as to be considered the same, and to identify those that clearly represent different levels.

Significant differences occur for the following items:

1. Sketching
2. Computer graphics
3. Experience with CAD using microcomputer systems.

Industry feels that these skills and experiences are being provided for significantly less than engineering schools do. A significant difference also exists in computer programming for computer graphics. This indicates that industry feels that there is significantly more provision for this skill than engineering schools do.

Summary of Conclusions Based on Comparison of the Two Surveys

Based on the comparison of the two surveys, several conclusions can be drawn. However, one overall conclusion is indicated and relates to all others. It can be concluded that, in general, engineering schools are doing a commendable job in attempting to be responsive to the needs of industry. In addition, the following conclusions can also be drawn:

1. Industry and engineering schools disagree significantly on the importance of 3-D geometric

modeling. However, the two groups agree on the level of provision this skill is receiving. Therefore this is not an area that requires improvement in the engineering curriculum.

2. Industry and engineering schools disagree significantly on the importance of problem solving analysis with CAD systems. However, the two groups are in agreement on the level of provision this item is receiving. Therefore this is not an area that requires improvement in the engineering graphics curriculum.

3. Industry and engineering schools disagree significantly on the importance of existing hardware and software "user" skills. However, the two groups are in agreement on the level of provison this item is receiving. Therefore this is not an area that requires improvement in the engineering graphics curriculum.

4. Industry and engineering schools agree on the importance of computer graphics. However, the two groups disagree significantly as to the level of provision this item is receiving. Therefore this is an area that requires improvement in the engineering graphics curriculum.

5. Industry and engineering schools agree on the importance of experience with CAD or CADD using microcomputer systems. However the two groups disagree significantly as to the level of provision this item is receiving. Therefore, this is an area that requires improvement in the engineering graphics curriculum.

6. Industry and engineering schools disagree significantly on both the level of importance and the level of provision for sketching. Therefore this is an area that requires modification in the engineering graphics curriculum.

7. Industry and engineering schools disagree significantly on both the level of imporatnce and the level of provision for computer programming for computer graphics. Therefore, this is an area that requires modification in the engineering graphics curriculum.

Conclusions Based on the Hardware and Software Items for the Academic Survey

The final purpose of the study was to identify what types of hardware and software are being used to achieve objectives in engineering graphics, and what configurations appear to work well in an educational environment.

Based on the analysis and discussion, the following conclusions were drawn:

1. Microcomputer systems appear to be used the most (52.4%) to achieve objectives in engineering graphics. The average rating for these systems by the respondents was (3.27) "good" to "very good".

2. Microcomputer system use in engineering graphics is increasing.

3. Software programs obtained from commercial venders are used more (60.7%) than any other type of software. The average rating for this software by respondents was (3.35) "good" to "very good".

4. The use of commercial software programs for engineering graphics is increasing.

5. The most frequent microcomputer systems used by the respondents is the IBM PC (45%) followed by the Apple II (21%).

6. The most frequent mainframe computer system used by the respondents was the Digital Equipment Corporation VAX system computers (52%).

7. Relatively few commercial turnkey CAD systems are used by the respondents. Of the 5 respondents to the item, 2 use Computervision systems.

8. There is no single specificly named software program for engineering graphics that stands out as being used more than any other, neither in-house, commercial, or user group.

Recommendations

The major purpose of this study was to evaluate the state of the curriculum in engineering graphics. Specifically, the impact of computer graphics on instruction in engineering graphics. This study was focused on engineering programs and not technology, applied technology or vocational programs. In order to view the recommendations of this study in perspective, it must be understood under what circumstances each of the samples responded. The industrial respondents completed the survey using their current understanding of their individual needs and the situation as it exists now. The academic respondents completed the survey using their knowledge of the state of affairs in education at the present time. Also, the engineering students infered about by the academic responents, will not become part of the industrial workforce for at least two years. On this basis, two types of recommendations are presented; practical recommendations and suggestions for improving the engineering graphics curriculum, and recommendations for further study.

Based on the results of this study, the following recommendations for curriculum development are made:

1. The engineering graphics curriculum should not discontinue teaching of traditional engineering graphics, but, continue to emphasize these capabilities in engineering students.

2. The engineering graphics curriculum should emphasize the development of skills in freehand sketching as a means of communicating technical information.

3. The engineering graphics curriculum should emphasize the use of available software to do computer graphics, as opposed to relying on computer programming as a teaching technique.

4. The engineering graphics curriculum should provide experiences with a variety of computing hardware. This hardware should include mainframe, microcomputer and personal computers. The survey results, however, indicate that microcomputers and personal computer technology will be a visable feature in industrial settings.

5. Engineering schools should continue to develop and expand the area of computer graphics within the engineering graphics curriculum. Considering the importance of both old and new technology, it is recommended that a required equivilent of a 4 credit course be devoted to engineering graphics. This course or courses should contain the equivilent of 2 semester hours of a traditional form of engineering graphics, including sketching, basic orthographic projection theory and other spatial concepts. This course or courses should also contain the equivilent of 2 semester hours devoted to computer graphics, including provision for computer modeling and computer-aided drafting.

6. Because the technology in the area of computer graphics advances quite rapidly, it is extremely important to keep informed of changes and develpments. It is therefore recommended that an ongoing relationship be formed with industrial representatives. This relationship can be beneficial to all parties concerned.

The completed study involved a comparison of industry and academia on the importance and provision of identified skills and experiences. This comparison became the basis for recommendations to improve the engineering graphics curriculum. Additional information could be obtained from inclusion of a third group. If engineering schools are to be responsive to the needs of industry, this must mainfest itself in responsiveness to engineering students themselves. It is therefore recommended that research be conducted using a third group containing recent engineering graudates who are working in industry.

The survey instrument used in this study was valuable in determining the levels of importance of several identified skills and experiences, as seen by industry and engineering schools. However, the instrument was probably responsible for generally lower levels of provision than for respective levels of importance. To take into account the phenomena of downgrading levels from importance to provision, it is recommended that research be performed to replicate this study and to improve the measurment of these needs in general.

The technical terms used in this study were intended to be understood in their broadest sense of definition. The term "computer graphics" can be thought of as a general heading under which many activities can take place. These activities might be: Computer-Aided Design (CAD), Computer-Aided Design Drafting (CADD), Computer-Aided Manufacturing (CAM), or Computer-Aided Engineering (CAE), etc. Unfortunately, these terms are used differently by different populations of people. It is therefore recommended that research be conducted to define what activities are performed within each of these computerized areas. This work should have as a goal, to implement a standardized usage of these important terms. In this way, all persons involved on a day-to-day basis and persons reviewing literature and research will have a common base for discussion and communication.

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THE UNIVERSITY OF TEXAS AT AUSTIN
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AUSTIN, TEXAS 78712

Department of Mechanical Engineering
Department Office, 512 471–1136
Chairman, 471–1131

June 5, 1984

Professor Jon Jensen
Mechanical Engineering Department
Marquette University
Milwaukee, Wisconsin 53233

Dear Jon,

I was delighted to read your dissertation proposal and I feel very positive about its value as a research topic. I would encourage you to conduct a rigorous scientific study on your industrial and academic surveys. We are at a point in our engineering graphics field where a well-documented report on modern graphics skills required in industry would be beneficial to all of us as academicians. The real question, of course, is how do we shape our courses to meet this new requirement?

I feel that the major impact of your dissertation could be the development of a modern curriculum for Engineering Graphics. Perhaps you could propose a model 3-credit course that would best satisfy the requirements of your earlier surveys and that would properly place computer graphics within the discipline of engineering graphics.

Some of the issues that I feel your dissertation should address are:

a) The incorporation of automated drafting for working drawings.

b) Whether programming should be taught as a part of the computer graphics effort in engineering graphics.

c) A systematic study of the hardware systems to be used in computer graphics.

d) What about the issue of design projects in engineering graphics?

e) What manual drawing skills and visual/spatial skills should be retained from traditonal graphics coursework?

I have annotated some comments on the proposal copy you sent to me. Please do not take my critique too seriously, but they were just some thoughts I had as I was reading the manuscript.

Also, I have enclosed some reprints that may be of interest to you. One of the papers is a result of the survey on computer graphics implementation in the freshman year which was conducted at Texas A&M in 1982. They may be a little antiquated, but will show you the trend two years ago. A second paper presents our plans here at the University of Texas for incorporating automated drafting into the engineering graphics course. We envision eventually doing away with manual drafting machines, but plan to retain some requisite for manual sketching in both orthographic and isometric form.

I would be much interested in your progress in this research study. Please feel free to contact me as you wish. I trust I will see you in Salt Lake City.

Sincerely Yours,

Ronald E. Barr
Associate Professor

OSU

The Ohio State University

Department of
Engineering Graphics

2070 Neil Avenue
Columbus, Ohio 43210

Phone 614 422-7923

Sept 4, 1984

Professor Jon K. Jensen
Department of Mechanical Engineering
Marquette University
Milwaukee, WI 53223

Dear Jon:

Summer school is at last over and I'm trying to do things that should have been done before now. We have a couple of weeks before getting back to the grind again. Duff has gone to Purdue and two new faculty (including Frank Croft) have arrived. I think we're going to have a real good department.

Our workshop didn't go. Only five people signed up for it and we didn't think that it was worth running for that small a group. Apparently this same "phenomenon" occurred at other places as well.

You have picked a very good topic for your dissertation. The more that can be done to find out about the place of computer graphics in engineering education, the better! If you haven't already revised the draft, there are a few changes I would suggest in the writing (I can always find "other's errors" - but miss mine). Content, I think, is OK.

For what it's worth, here are a few of my ideas about engineering graphics, computer graphics, and computer programming. In every area where computers "might" be able to do the job, individuals MUST have adequate knowledge and experience with fundamentals. This includes mathematics, spelling, writing and graphics. Perhaps the most important concept is that the computer is nothing more than a very valuable tool!

As I'm sure you're aware, numbers of schools dropped their engineering drawing or graphics courses because there was no "science" in the material covered in these courses. Recently, some schools which had retained some engineering graphics have replaced manual graphics with computer graphics. Those responsible for this trend seem to feel that users of computer graphics systems do not need knowledge of graphics before they can use the computer as a tool!

However, everytime I talk with people in charge of computer aided drafting systems regarding the background in graphics and computer graphics they would like the people they hire to have I get the following results. First of all, they want their people to have a good background in drafting. They really don't care whether they have any experience in computer graphics or not. "We can provide the computer graphics training as long as they have the drafting background!" However, they generally agree that an exposure to some computer aided drafting would be fine. While they would, of course, like this training to be on the system they are using, they also agree that computer graphics concepts and familiarity can be obtained on a relatively inexpensive system in a comparatively short period of time.

Similarly, those who are using engineers in computer aided design say that they need a good background in graphics. One individual wanted to know if the universities were no longer giving courses in descriptive geometry!

Some schools which advertised that they would provide training in computer graphics for persons who had NO background in drafting have closed shortly after opening.

I also believe that every engineering student should have completed a course in programming fundamentals. It does not particularly matter what computing language is used as long as principles of programming are emphasized. Students who complete a course of this nature are learning aboutproblem solving and use of a valuable engineering tool. This course should be given as early as possible in the engineering student program.

Some computer graphics programming should be included - perhaps as part of the computer programming mentioned above. One benefit received from this should be to teach the students the relationships between numerical representation of a line or surface and the graphical representation of the same geometric entities.

Students should be using interactive computer graphics throughout the entire four years of their engineering program. There are many subject matter areas (for example, engineering mechanics) where graphic tutorials would provide a terrific learning experience for many students.

In addition, the degree granting departments should include some form of interactive computer graphics expereience at the upper undergraduate and graduate levels. Mechanical and civil engineering might include finite element analysis in some of their design courses. Surely every department must teach material which could include some use of interactive computer graphics as part of one or more courses.

I hope this will encourage you and also be useful. If there is anything else I can do, just let me know. I would like to visit Milwaukee one of these days - one reason being I have MATC's CAD package. Have not yet been able to get an Apple Tablet, but it can still be used (after a fashion) without this.

Best regards,

Bob

Robert D. LaRue. P.E.
Professor

Appendix B

Department of Mechanical Engineering
MU Marquette University
Milwaukee, WI 53233
414-224-7259

October 11, 1984

Dear

Your name was received from the membership list of the National Computer Graphics Association. The purpose of this letter is to solicit your kind assistance with a short but important survey. It should require no more than a few minutes of your time and a stamped envelope has been provided for your immediate response.

This is an educational survey concerned with Computer Graphics in the engineering curriculum. If you are unable to answer the questions from your occupational standpoint, I would appreciate it if you would please route this survey to another person in your organization.

Engineering colleges have been struggling with how to implement Computer Graphics most efficiently into the curriculum. The literature suggests that a course in Engineering Graphics is the most common location for first experience in Computer Graphics or CADD. However, there is little agreement on what this experience should consist of. The following survey contains topics most cited in the literature as relevant experiences for engineers. By answering these brief questions you can help generate substansive evidence for development of this important area of technology.

I thank you ahead of time for your much needed assistance, and would welcome any general comments you would like to add. The results of this research will be published; however, I would be pleased to send you a summary of the results if you desire.

Yours very truly,

Jon K. Jensen
Assistant Professor

JKJ/jmm

Enclosure

For each of the following items, circle the number that best describes your feeling about (1) HOW IMPORTANT the item listed is to the skills needed by engineers, and (2) HOW WELL PROVIDED with with this skill are present engineering graduates.

1 = LOW IMPORTANCE OR PROVISION
5 = HIGH IMPORTANCE OR PROVISION

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	Traditional engineering graphics abilities	1 2 3 4 5
1 2 3 4 5	Spatial visualization	1 2 3 4 5
1 2 3 4 5	Descriptive Geometry	1 2 3 4 5
1 2 3 4 5	Sketching	1 2 3 4 5
1 2 3 4 5	Computer Graphics	1 2 3 4 5
1 2 3 4 5	Combination of traditional engineering graphics and computer graphics	1 2 3 4 5

In regard to skills that could be developed in a course in Engineering Graphics, circle the number that best describes your feeling about (1) HOW IMPORTANT the item is to the skills needed by Engineers, and (2) HOW WELL PROVIDED with this skill are present engineering graduates

1 = LOW Importance or LOW provision
5 = HIGH Importance or HIGH provision

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	3-D Geometric modeling	1 2 3 4 5
1 2 3 4 5	Computer-Aided Drafting	1 2 3 4 5
1 2 3 4 5	Computer programming for computer graphics	1 2 3 4 5
1 2 3 4 5	Problem Solving analysis with CAD system on graphics designs.	1 2 3 4 5
1 2 3 4 5	Existing hardware/software "user" skills (mechanics of using a system)	1 2 3 4 5
1 2 3 4 5	Experience with Commercial turnkey CAD or CADD system hardware/software	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using microcomputer systems	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using mainframe computer systems	1 2 3 4 5
1 2 3 4 5	Other ______________________	1 2 3 4 5

I would like a summary of survey results

Yes No

Department of Mechanical Engineering

MU Marquette University

Milwaukee, WI 53233
414-224-7259

October 11, 1984

Dear

Your name was received from the membership list of the Engineering Design Graphics Division of the American Society for Engineering Education. The purpose of this letter is to solicit your kind assistance with a short but important survey. It should require no more than a few minutes of your time and a stamped envelope has been provided for your immediate response.

This is an educational survey concerned with Computer Graphics in the engineering curriculum. If you are unable to answer the questions from your occupational standpoint, I would appreciate it if you would please route this survey to another person in your organization.

Engineering colleges have been struggling with how to implement Computer Graphics most efficiently into the curriculum. The literature suggests that a course in Engineering Graphics is the most common location for first experience in Computer Graphics or CADD. However, there is little agreement on what this experience should consist of. The following survey contains topics most cited in the literature as relevant experiences for engineers. By answering these brief questions you can help generate substansive evidence for development of this important area of technology.

I thank you ahead of time for your much needed assistance, and would welcome any general comments you would like to add. The results of this research will be published; however, I would be pleased to send you a summary of the results if you desire.

Yours very truly,

Jon K. Jensen
Assistant Professor

JKJ/jmm

Enclosure

For each of the following items, circle the number that best describes your feeling about (1) HOW IMPORTANT the item listed is to the skills needed by engineers, and (2) HOW WELL PROVIDED with with this skill are present engineering students.

1 = LOW IMPORTANCE OR PROVISION
5 = HIGH IMPORTANCE OR PROVISION

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	Traditional engineering graphics abilities	1 2 3 4 5
1 2 3 4 5	Spatial visualization	1 2 3 4 5
1 2 3 4 5	Descriptive Geometry	1 2 3 4 5
1 2 3 4 5	Sketching	1 2 3 4 5
1 2 3 4 5	Computer Graphics	1 2 3 4 5
1 2 3 4 5	Combination of traditional engineering graphics and computer graphics	1 2 3 4 5

In regard to skills that could be developed in a course in Engineering Graphics, circle the number that best describes your feeling about (1) HOW IMPORTANT the item is to the skills needed by Engineers, and (2) HOW WELL PROVIDED with this skill are present engineering students

1 = LOW Importance or LOW provision
5 = HIGH Importance or HIGH provision

HOW IMPORTANT		HOW WELL PROVIDED
1 2 3 4 5	3-D Geometric modeling	1 2 3 4 5
1 2 3 4 5	Computer-Aided Drafting	1 2 3 4 5
1 2 3 4 5	Computer programming for computer graphics	1 2 3 4 5
1 2 3 4 5	Problem Solving analysis with CAD system on graphics designs.	1 2 3 4 5
1 2 3 4 5	Existing hardware/software "user" skills (mechanics of using a system)	1 2 3 4 5
1 2 3 4 5	Experience with Commercial turnkey CAD or CADD system hardware/software	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using microcomputer systems	1 2 3 4 5
1 2 3 4 5	Experiences with CAD or CADD using mainframe computer systems	1 2 3 4 5
1 2 3 4 5	Other ______________________________	1 2 3 4 5
1 2 3 4 5	______________________________	1 2 3 4 5

1. What type of hardware system is used by your students in Engineering Graphics to achieve your instructional objectives in Computer Graphics? (Circle "NONE" if Engineering Graphics students do not study computer graphics)

   Mainframe Computer   Micro-Computer   Batch   Turnkey System   None

2. Briefly, what specific hardware system(s) do your students in Engineering Graphics use to achieve objectives in Computer Graphics? (e.g., VAX 11/780, IBM PC, Apple, etc.)

3. What is your personal appraisal of this hardware's ability to satisfy instructional objectives for students in Engineering Graphics? (Circle one)

   Poor   Fair   Good   Very Good   Excellent

4. What software system(s) are used by your students in Engineering Graphics to achieve your instructional objectives in Computer Graphics? (Circle "NONE" if Engineering Graphics students do not study Computer Graphics) you may circle more than one.

   In House Written   Commercial Vendor   User Group   Other   None

5. Briefly, name what specific software system(s) your students in Engineering Graphics use to achieve instructional objectives in Computer Graphics? (e.g., "Fastdraft", MOVIE.BYU, "Your Acronym")

6. What is your personal appraisal of the software's ability to satisfy instructional objectives for students in Engineering Graphics? (Circle one)

   Poor   Fair   Good   Very Good   Excellent

   I would like a summary of the survey results (Circle one)

   Yes   No

This dissertation has been approved by the following committee:

______________________________ Chairperson

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