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Entry-Level Computer Aided Design and Drafting Skills

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ENTRY-LEVEL COMPUTER AIDED DESIGN AND DRAFTING SKILLS

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Introduction

The computer industry is now the most dynamic ever to be developed and will continue to be so (Mileaf, 1982). There are 10 million computers at work worldwide (Quantz, 1982), and studies have confirmed that computer aided design and drafting (CAD) is one of the fastest growing segments of the computer industry.

The new buzz word in training circles is CAD (Keenan, 1982), and though elements of CAD have been around since the mid-1950's, they have been developing very slowly (Quantz, 1982), and for good reason. Very high costs of CAD systems, scarcity of pertinent software, and a barrier between the design professionals and the computer professionals have all slowed down growth (Mileaf, 1982). But ever since 1963, methods of designing and drafting have been changing rapidly. In that year, Ivan Sutherland implemented a computer graphics software program called Sketchpad as a part of his doctoral dissertation at the Massachusetts Institute of Technology (MIT). This first computerized drafting program used unique hardware and was not easily transported to other computing systems. But hardware has also been developing rapidly; computer memory prices have dropped, special purpose graphic computers have been developed, and computers have been improved to increase their speed and capabilities (Teicholz, 1983).

Computer aided design and drafting systems are used by mechanical, structural and electrical engineers for printed circuit board design, mapping, problem solving in architecture, construction, and a host of other fields (Teicholz, 1983). These areas will grow as a result of implementing CAD systems (Mileaf, 1982; Teicholz, 1983). As a drafting tool, CAD is used for reviewing an existing drawing and making very rapid modifications, eliminating the need to carry out dull repetitive tasks, and for quick reproduction of existing drawings. As a design tool, CAD can make comparisons of differing designs, do complex structural and functional analyses, and demonstrate the operation and performance of products without the need for expensive prototypes (Beercheck, 1982; Black, 1982; Coiro, 1982; Hamilton, 1982; Krouse, 1982).

Because of the tremendous number of benefits which CAD systems offer, they are becoming more and more common in education and industry (Marshall, 1982; Voelcker, 1982). Some have gone as far as to say that firms not getting involved in CAD will not be able to compete in the future (Engineering, 1981).

There are also many educational opportunities which result from CAD technology. There is a tremendous benefit to be realized by educating students with the advanced technology which they will use ("Learning CAD/CAM," 1981). More and more educational institutions are realizing the impact which CAD is having and are seeking to implement curricular structures which will address this new technology ("UCLA Students," 1982; "Turnkey graphics," 1981). There is a need, however, to know what the important elements of computer aided design and drafting are so they can be better implemented in the classroom.

Many educators select a CAD system largely on the basis of its cost and then set about to teach the capabilities of that specific system. CAD system manufacturers recommend teaching those concepts which pertain to their system. But both of these approaches are very narrow in application for the student.

With the complexity and diversity of different systems, it would be nearly impossible to educate a student to be able to operate all CAD systems. An introduction to entry-level skills compiled from operators of various brands of CAD systems would therefore be helpful in achieving entry-level competency. A review of the current literature revealed insufficient information on what elements of CAD are necessary for entry-level CAD system operators. Yet this information is needed because of the impact which CAD systems are having in our society.

The potential for applications of CAD is tremendous (Quantz, 1982), but until 1980, educators left CAD training up to industry. Now there is a need among industrial educators to know what aspects of computer aided design and drafting are important and need to be taught. Bro (1983) states that, "finding the appropriate mix of the traditional drafting fundamentals and CAD instruction is a major concern of professors of drafting and design technology." The explosion of computer aided design and drafting use has created a tremendous demand for people trained in system use (Voelcker, 1982), but improvement is needed in the area of learning to use these systems. Gondert (1982) says:

> Universities will play a significant role in training the needed people. More and more private and state universities are building departments to train students in CAD and with rapid acceptance of this technology by industry, it is

likely that every university will have a design program by the end of the decade. Universities are in a tremendous position to help realize the potential of this new technology. "Universities face three challenges: 1) to train...for using computer aided systems so that education will meet industry needs, 2) to teach...the fundamentals of CAD and its implementation, and 3) to provide an environment supportive of research in this area" ("UCLA students," 1982). Another CAD instructor states that, "we are still in the introductory stages of CAD, but students who have gone to industry with training have found the transition easy to make" (Keenan, 1982). Yet, to meet any of these three challenges, there is a need to first know what elements of CAD should be taught.

Statement of the Problem

What entry-level competencies do industrial personnel consider to be important for operating a CAD system?

Research Questions

1) What technical knowledge and manipulative skills are necessary for entry-level CAD system operators?

2) What is the ranked importance of these CAD system entry-level competencies?

Purposes of the Study

The purposes of the study were to:

1) determine the entry-level competencies necessary for CAD system

operation, and

2) rank in order of importance the competencies identified to be necessary for entry-level CAD system operators.

Assumptions

The following assumptions were made for this study:

1) responses were accurate and honest, and

2) respondents were knowledgeable about CAD system operation.

Limitations

The study was limited by the following:

1) the instrument used in this study was not tested for reliability.

Delimitation

The study was delimited by the following:

1) the population consisted of only Iowa CAD system users.

Definition of Terms

BASIC is a programming language used for small-scale computers (Ryan, 1979).

Bit is a contraction of 'binary digit'. One of the two characters (0 and 1) used in binary notation (Chandor, 1981).

Cathode ray tube is a display screen for viewing graphics or drawing new graphic shapes to be stored by the computer.

Channel is a physical path along which data may be transmitted or stored (Chandor, 1981).

Chip is a single device consisting of transistors, diodes and other components forming the essential elements of a central processor on a wafer sliced from a crystal of silicon (Chandor, 1981).

Digitize means to transform a graphical shape into a digital signal for storage (Ryan, 1979).

Interface is a common boundary between systems or devices (Chandor, 1981).

Light pen is a device which detects the presence of light when held to a CRT (cathode ray tube) screen (Ryan, 1979).

Memory is an internal store of information which is immediately accessible (Chandor, 1981).

Microcomputer is a tiny computer in which the processor and memory are mounted on a single board, with the processor on a single small chip (Jefferson, 1982).

Minicomputer is a small special-purpose computer with a word length of 18 bits or less and about 4000 of memory (Ryan, 1979).

Plotter is a device which allows the computer to control a pen moving over a piece of paper to make an engineering drawing (Ryan, 1979).

Printer is an output device such as a matrix printer, line printer, teletype, and video terminals (Ryan, 1979).

CHAPTER II

Review of Related Literature

Background

Certain elemtents of computer aided design and drafting (CAD) have been around since the mid-1950's (Quantz, 1982), but growth in this area has been slow. In 1963, a stimulus was provided by Ivan Sutherland while working on his doctoral dissertation at the Massachusetts Institute of Technology. He implemented a computer graphics software program called Sketchpad, but this first program used unique hardware, and was not easily transported (Teicholz, 1983). Others were also involved in researching the concept of CAD during this time. Ed Jacks and the Design Augmented by Computers (DAC-1) team at General Motors Research labs and S. H. "Chase" Chasen with his Man-Computer Graphics at Lockheed-Marietta were two such people. A team at General Electric started with an IBM computer, a five inch cathode ray tube (CRT), a programmable film train, and a 19" inch screen slaved to the system. They connected a light pen to a sense switch to make the first graphic light pen (Neil, 1983).

In the late 1960's, with the introduction of a 16-bit minicomputer and a low-cost Tektronix storage tube, the advent of affordable CAD began (Albert, 1982). Now the number of system installations increases each year as more and more users take advantage of the technology (Marshall, 1982).

Recent developments

The first minicomputer CAD/CAM (computer aided design/computer aided manufacturing) system was invented in 1970, when Integrated Computer Systems (ICS) company at Irvine, California ran CAD/CAM on a 16-bit REDCOR minicomputer. Nearly all CAD/CAM system developments which have been made since then have stemmed from the work of ICS. Then in 1974, Computervision Company bought the rights to ICS software, making it their exclusive property (Neil, 1983). Computervision is now one of the largest manufacturers of CAD systems in the United States.

Advances in CAD technology

Improvements in computer technology are causing a tremendous increase in the number of CAD system sales. Reduction in costs is significant; hardware costs are coming down at the rate of 50% each year. Chip density and the number of transistors on the chip translate directly into cost per function. A decade ago the most advanced chip contained less than 100 transistors, and a 64,000 bit chip was forecasted to arrive between 1982 and 1985; it arrived in 1979 (Blauth, 1981).

Software improvements are being fueled by hardware improvements. Color capabilities of CAD systems will become more available and useful and major improvements will be made in resolution. The range and depth of CAD software applications will continue to broaden over the next 10 years. Software programs and packages will become more popular and available, as the total investment in software in the 1980's exceeds one billion dollars.

Impact of CAD systems

For years drafting and design functions have been performed manually. Compasses, triangles, T-squares, and pencils have been used for drafting and complex mathematical formulas, calculations, and a multitude of prototypes were used for designing. This is all being changed by CAD systems, yet the human element will never be eliminated. Rather, productivity and enthusiasm of the worker are being increased while work time is being decreased (Black, 1982; Hamilton, 1982; Teicholz, 1983; Lerro, 1983).

CAD system benefits for drafting

There are numerous benefits which CAD systems provide. In the realm of drafting, many systems will automatically dimension and letter drawings, and then produce multiple drawings from as many views as desired (Beercheck, 1982). CAD systems can copy repetitious details, automatically draw standard symbols, translate or rotate a portion of a drawing, generate a mirror image of a part, and reproduce multiple parts from one initial shape (Black, 1982). Drawing management and maintenance is improved, and early detection and correction of mistakes saves valuable time and money (Teicholz, 1983). McDonnel Douglas and General Dynamics have speeded production of their F-100 turbofan jet engine by several years as a result of implementing CAD systems. The 3500 drawings associated with this engine are constantly updated using CAD (Lerro, 1983). Krouse (1980) reported that CAD can be five times faster at these operations than manual drafting techniques (Krouse, 1980). In 1982, Black stated that CAD was 33% faster on complex drawings and 10% faster on simple drawings (Black, 1982). Today, systems are even more powerful.

CAD system benefits for design

The benefits realized from CAD systems in the area of design are even more numerous and financially profitable than those benefits associated with drafting. Major strengths of CAD systems lie in the areas of three dimensional design, engineering analysis of designs, and modeling of parts which are not feasible by manual techniques (Black, 1982). Systems can be used to redesign parts using less material, and to determine the correct material for a design by substituting stress-strain curves for different materials into an analysis program before ever experimenting with molds. Parts can be designed faster, with greater accuracy, higher reliability, and lower manufacturing costs. Because of the reduced work time, designers can spend more time on alternative designs. The computer can also be used to examine static loads, impact loads, or effects of vibration prior to cutting steel (Henry, 1982). Images can be scaled to a larger or smaller size, giving a much clearer representation of how parts fit together (Beercheck. 1982). Proof cycles of machining operations can be run and verified before ever starting any motors. Computers can be used to simulate an operation faster than it will happen in real life, here again saving the time and cost of making prototypes. Computer programs can build in safeguards such as minimal thicknesses or clearances (Libby, 1982). After making elaborate designs on CAD systems, a bill of materials can then be automatically generated (Beercheck, 1982).

Cost and productivity improvements

These benefits all add up to an attractive bottom line on company reports. International Harvester reports designing engines in 67% of the time it took to do the design manually. Quality is improved and production cycles are shortened by using CAD. Systems are usually purchased to increase productivity and they usually give this result. According to Dr. Khalil Taraman, chairman of the Mechanical Engineering Department of the University of Detroit, CAD has been proven to make engineers three to twenty times more productive ("Learning CAD/CAM," 1981). Blauth (1981) reports that use of CAD increases productivity by three, ten, or twenty times while also improving staff morale. Six designers on a CAD system could do the work of 19 designers using manual methods. Even the decline in national productivity could be reduced (Billhart, 1982), and the downward drift of the economy could be reversed ("Experts say CAD/CAM," 1980). New product strategies and increased documentation of previous work to avoid repeating errors will also help to improve productivity (Billhart, 1982). Many CAD system suppliers claim productivity boosts of 3:1 or 4:1 but some claim a 20:1 increase (Black, 1982).

Aircraft companies make extensive use of CAD systems. Assembly quality is improved and time is reduced. Boeing used their CAD systems for the 767 and then assembled the aircraft without using a single shim, something which is quite uncommon in this industry (Tortolano, 1981). Planes can be "flown" on missions before cutting a single piece of steel (Krouse, 1979).

<u>Demand for CAD system operators</u>

Initially, a considerable portion of a CAD system's use in an industry is for familiarization and training sessions for new operators. But people who already have operating skills are in greater demand, at higher salaries (Foundyller, 1980). Local industries in the Minneapolis-

St. Paul area, for example, can use as many graduates in computer aided design and drafting as vocational schools can provide (Keenan, 1982).

The need for CAD system operators is great now and by the end of the decade the need will be tremendous ("Learning CAD/CAM," 1981). Many colleges and universities have realized this need, and more and more post secondary schools are providing training in CAD. But curricular implementation is more difficult than computer implementation (Plummer, 1981). Nevertheless, some educators are accepting the challenge. The University of Detroit has a program involving CAD that is filling the local need for such trained personnel. There are even plans for a degree program in CAD/CAM. At present, the concept is in an exposure status, but if funds were available, CAD would progress very quickly ("Educational institutions", 1980). Graduates of the University of Northern Iowa's industrial technology program who are now employed in computer aided design have written and expressed the great value that their training has had for them (Bro, 1983).

Computer aided drafting entry-level skills

Because of the newness of CAD, many educators find themselves struggling to determine what they should be teaching. Reporting on his study of computer aided drafting, Goetsch (1983) says that the question is: "What entry-level CAD skills do our students need?" And the answer is critical. He states that an analysis of entry-level CAD skills reveals that work needs to be done in all domains of learning: cognitive, psychomotor, and affective. A breakdown of 25 percent cognitive and affective and 75 percent psychomotor activities have proven to be successful. The breakdown of activities within these areas should occur as follows. Within the cognitive domain, activities should attempt to develop proficiency in these tasks:

1) Learning CAD terminology and defining CAD as a concept.

2) Comparing CAD and manual drafting in terms of such features as speed, accuracy, consistency, and neatness.

3) Explaining CAD's major benefits and applications.

4) Listing the various drafting functions the CAD system can perform--which include any task that can be performed manually--and explaining how they are performed.

5) Listing and explaining the uses of CAD hardware and software components.

6) Explaining the difference between a CAD system operator and a CAD technician.

Activities in the psychomotor domain should encourage proficiency in:

1) Input tasks: keystroking (typing); hand-cursor manipulation; light-pen manipulation; screen-cursor control; digitizing; entering system commands by typing and menu activation...

2) Processing tasks: editing, data storage and file creation, data retrieval...

3) Output tasks: printing, plotting, and hard-copying.

Affective learning activities should focus on development of these attitudinal characteristics:

1) Willingness to learn.

2) Creativity and innovation (Goetsch, 1983).

CAD in education

Paul Ellefson, an instructor at the Hennepin Technology Center (University of Minnesota), says that "CAD does not shortcut basic techniques, nor is it designed to allow instructors to pass lightly over the fundamentals. Rather it eliminates repetitive pen and pencil drawing" (Keenan, 1982). Bro (1983) agrees with this, stating that "instructional CAD should supplement rather than supplant fundamental drafting knowledge and skill development." Educators at the Macomb Community College in Michigan concur with this viewpoint and provide students with traditional drafting training as well as CAD experience (Welsh, 1982).

The University of California at Los Angeles boasts a program that is determined to graduate engineers with skills in the state-of-the-art production technology using computer graphics. They currently have two pioneering courses in CAD. Students have literally exchanged their drafting boards, T-squares, and pencils for computer terminals and light pens ("UCLA students," 1982). At the Western Illinois University, CAD courses have become so popular that from 1979 to 1980, enrollment went from 12 to 42 students and is still growing. Terminals are kept in use 16 hours a day, seven days a week ("Turnkey graphics," 1981).

Uses of computer aided design and drafting in education are not new. In the late 1960's at the University of Missouri-Rolla (UMR), early storage tube displays could be driven by an IBM system using a home-made channel interfacer. By 1973, this hardware was supporting undergraduate instruction. By 1975, a time-sharing BASIC (Beginners All

Purpose Symbolic Instruction Code) system was augmented. The greatest good was achieved by self-motivated students (Plummer, 1981).

Future of CAD

It seems that the uses and applications of computer aided design and drafting systems will only increase in the years to come. Mileaf (1982) feels that the steady growth of computers will make them as common as the typewriter in a few years. By 1976, almost 30% of the active architects and engineers were involved with computers. This grew to 35% in 1978, 59% in 1979, 65% in 1981, and 90% active involvement is expected by 1986. Between now and 1986, 10,000 more architectural and engineering firms report plans for using computers (Mileaf, 1982). An Arthur D. Little study suggests that techniques which comprise CAD will experience rapid worldwide growth, averaging an annual 25% up to 1984 ("Experts say CAD/CAM," 1980). Purchase of engineering and drafting CAD workstations will exceed 25,000 in 1983, with 40,000 to 50,000 new operators arising to operate these systems (Raker, 1982). Kohn (1981) projects CAD market growth to increase from 510 million dollars in 1981 to 1.9 billion dollars in 1986.

Engineers of the 1980's are expected to rely heavily on CAD systems to carry out their functions. And because of the increased capability and decreased cost of systems, smaller companies will also make purchases of CAD systems (Billhart, 1982; Krouse, 1979). Experts also predict that by 1985, 90% of all mechanical drafting will be done by CAD systems, and by 1987, all tools will be designed through the use of computer graphics (Krouse, 1979).

The ultimate factory is one that is run totally by computers, robots, and automated machines; this has long been the dream of engineers. With the current growth of technology, including that of CAD and CAM, this could be feasible by the end of the century (Krouse, 1981).

CHAPTER III

Major Methodological Procedures

Population

The population for this study was made up of industrial personnel who were currently using computer aided design and drafting (CAD) systems in Iowa.

Element Selection

A review of the literature and discussion with University of Northern Iowa (UNI) faculty revealed no published listing of these CAD users. Names of computer manufacturers and drafting supply companies which manufacture computer aided design and drafting systems were obtained from the literature (see Appendix B for a list of periodicals used and Appendix C for a listing of the companies which were identified). The researcher then contacted sales representatives by phone from each company identified who were responsible for CAD system customers in the Iowa area (see Appendix D for a list of persons contacted). From these representatives a list was obtained of companies in Iowa which were using a CAD system (see Figure 1). In some cases, the personnel contacted at these companies referred the researcher to other Iowa CAD users not previously identified. A total of 14 Iowa firms using CAD systems was compiled (see Appendix E for all Iowa firms identified). Some of these firms received no instruments and other firms received instruments at several plant locations (See Appendix G for those receiving the instrument).

Instrument Development

Since a pretested instrument was not found which would accomplish the objectives of the study an instrument was developed by the researcher (see Appendix A). A text book analysis was completed to compile a list of fundamental drafting skills and concepts. Added to this were related

CAD System Suppliers Identified

Phone Contact Made with CAD System Suppliers

Iowa Firms Using CAD Systems Identified

Iowa Firms Using CAD Systems Phone Contacted

Number of CAD System Operators Identified

Figure 1. Procedure for identifying Iowa CAD system operators.

skills necessary to carry out CAD system operations. These were compiled from manufacturers brochures and from personal interviews. A section for collecting demographic data was also included. Face validity was used to sêlect items for the instrument.

Instrument review and pilot testing.

The instrument was compiled and a draft copy was given to a panel of experts to check for clarity and purpose. First, it was given to two UNI faculty members familiar with computers and CAD systems. Revisions were then made based on their written and oral responses. The revised instrument was given to a resident computer and CAD system expert at UNI for further critiquing. After a second revision of this instrument based on suggestions made, two research specialists were consulted regarding structure, clarity, and format. A final review was then made of the instrument before mailing.

Instruments were then mailed to CAD system sales representatives, drafting supply salesmen, industry personnel outside of Iowa, and industrial educators within and without Iowa for pilot testing (See Appendix F for a list of those receiving the instrument). A total of eleven instruments were sent out and ten were returned. These respondents were chosen on the basis of their knowledge of CAD system operation. They did not meet the criteria for being a part of the population.

In the cover letter, these respondents were asked to complete the instrument and also to comment on any aspect of it which they felt appropriate. Based on their responses, the researcher then edited and modified the instrument, for increased clarity and removal of items which were commented on as being sensitive and inappropriate items (See Appendix A for the cover letter and the final instrument).

The final instrument consisted of three sections. The first section obtained a rating of fundamental drafting skills and concepts important for CAD system operators.The second section dealt with related skills and experiences important in preparing to become a CAD system user. The third section provided background information on the CAD system and the company with which the respondent was associated. The procedure for developing the instrument is illustrated in Figure 2.

Instrument printing and mailing.

The instruments were printed at the University of Northern Iowa. In total, 187 copies were then distributed to the persons within the various companies in March 1983 (see Appendix G).

Data collection

The person(s) in charge of the CAD system(s) at each of the 14 firms identified as being part of the population were then contacted by telephone. They identified the number of CAD system operators within their company and were sent the appropriate number of instruments (See Appendix G for the names of persons who received the instruments). They were then responsible for distribution, completion, and return of instruments in the self-addressed stamped envelopes provided. Personnel from two companies could not be reached due to a temporary shut-down of operations. Therefore, an instrument was sent to one individual from each of these companies, without prior telephone contact. The specific number of instruments sent to each company is noted in Appendix H. Because of an approaching temporary shut-down of a local firm heavily involved with computer aided design and drafting, the researcher hand delivered 42 copies (total) of the instrument to three different plant locations.

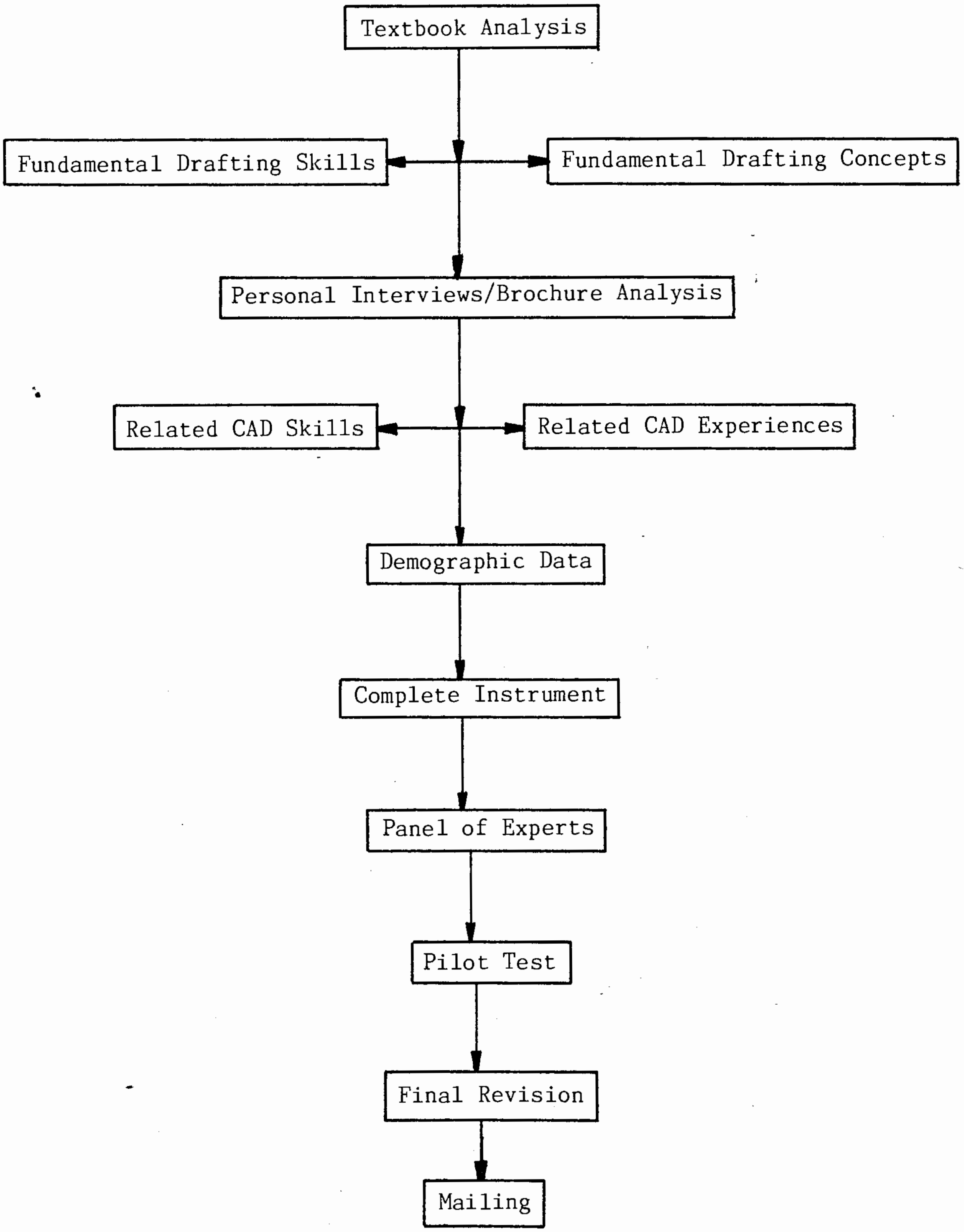

Figure 2. Procedure of instrument development.

CHAPTER IV

Analyses of the Data

Data from the survey made of Iowa computer aided design and drafting system users were manipulated using a subprogram of the Statistical Package for the Social Sciences. This work was done by staff of the Academic Computing Services of the University of Northern Iowa.

These computations produced the frequency, mean and standard deviation for every response. An overall ranking of each item's importance was obtained by placing computed mean values in numerical order. Table 1 presents the analyses of the data. Knowledge of geometric construction received the highest ranking. The data as a whole showed that the basic principles of drafting and design are still important in CAD system operation, but that skills which are repetitive (e.g., freehand lettering, line quality) in nature can be done by the CAD system without skill on the part of the operator.

The results of the second section of the instrument (skills and experiences related to CAD system operation) are presented in Table 2. The CAD operators thought that math skills (especially geometry and trigonometry) were very important, but said that computer knowledge and specific CAD experiences were of lesser importance. Typing skill even rated higher than general computer knowledge.

The analysis of data obtained in the third section of the instrument is divided into three categories: data on participating firms, data on CAD

Table 1

Ranking of Entry-level Skills and Concepts for CAD System Operators

Entry-level Drafting Skills	Mean[a]	Standard Deviation	Overall Rank Order
Geometric Construction	2.627	.600	1
Detail Drawing	2.599	.573	2
Sectional Views	2.525	.634	3
Assembly Drawing	2.475	.680	4
Auxiliary Views	2.400	.754	5
Use of Line Symbols	2.346	.720	6
Graphic Rotation of Views	2.333	.726	7
Coordinate Dimensioning	2.325	.821	8
Spatial Visualization	2.301	.897	9
Decimal Dimensioning	2.253	.821	10
Descriptive Geometry	2.170	.851	11
Drawing to Scale	2.149	.910	12
Third Angle Projection	2.138	.951	13
Metric Measurement and Dimensioning Standards	1.968	.947	14
Isometric Drawing	1.925	.875	15
First Angle Projection	1.728	1.032	16
Grid Line Dimensioning	1.609	.899	17
Oblique Drawing	1.541	.902	18
Line Quality	1.431	1.001	19
Fractional Dimensioning	1.406	1.134	20
Perspective Drawing	1.387	.958	21
Construction of Graphs	1.317	.904	22
Instrument Drawing	1.278	.963	23
Freehand Sketching	1.235	.956	24
Freehand Lettering	.727	.851	25
Mechanical Assisted Lettering	.400	.693	26

[a] Zero represents Not Important and three (3) represents Very Important fundamental drafting skills.

Table 2

Ranking of Related Skills and Experiences Necessary for CAD System Operators

Related Skills and Experience	Mean[a]	Standard Deviation	Overall Rank Order
Geometry	2.325	.805	1
Trigonometry	2.150	.870	2
Typing	1.830	.781	3
Algebra	1.811	.820	4
General Computer Knowledge	1.484	.881	5
Prior CAD Experience on Any Type of System	1.266	.927	6
Matrix Math	1.190	.887	7
Computer Programming	1.182	.778	8
Prior CAD Experience on an Equal System	1.146	.926	9
Calculus	1.000	.829	10

[a] Zero (0) represents Not Important and three (3) represents Very Important entry level skills and concepts necessary for CAD system operators.

systems used in the firms surveyed, and CAD system technical data. When asked concerning the total number of employees and the number of CAD operators in each firm, respondents answered in such a way that the data was rendered to be of minimal value. Respondents from the same firm gave conflicting responses; some gave figures for their division of the firm and others gave a figure which included the total firm.

The average length of time that the CAD systems had been installed was 3.81 years. The CAD operators who had been working with their systems for short periods of time could have given responses which were not completely accurate.

Data concerning the individual computer aided design and drafting systems used in the firms is presented in Table 3. The Computervision CAD system was in greatest use but this again was a result of the large number of operators who were John Deere employees. Only one respondent reported using an Auto-trol system and three were using a Calma system.

Table 3

Data on CAD Systems of Firms Surveyed

Brand of Systems	Percent
What is the brand name of your system?	
Computervision	72.2
Intergraph (M & S)	14.19
Applicon	10.49
Calma	1.85
Auto-trol	.061

Table 4 presents the analyses of the technical information related to the CAD systems used in the firms which were surveyed. Nearly two-thirds of the respondents used turnkey CAD systems and were not operating from a time-sharing system. Minicomputers were utilized by 75% of the respondents while less than 25% used a mainframe computer. Most operators could perform two- and three-dimensional operations on their systems but did not have color capabilities. The most common plotter was the electrostatic type.

Table 4

CAD System Technical Data

	Percent		
System Operation	Yes	No	No Response
Do you use time-sharing for your CAD system?	19.75	61.1	19.13
Is your CAD system set-up on a:			
Microcomputer?	1.85	73.4	24.6
Minicomputer?	75.3	12.34	12.34
Mainframe computer?	22.22	54.9	22.8
System Capabilities	Yes	No	No Response
Does your system have:			
2-D capabilities?	78.39	5.55	16.04
3-D capabilities?	91.35	0.0	8.64
Does your system have color capabilities?	19.13	79.6	1.23

Table 4 (continued)

Plotter Type			
Check the type of plotter your system uses:			
Flatbed plotter	32.7	9.25	58.0
Drum plotter	32.7	0.0	67.28
Electrostatic plotter	79.6	0.0	20.3

CHAPTER V

SUMMARY, RESULTS, DISCUSSION, AND RECOMMENDATIONS

Summary

The purposes of this study were to:

1) determine entry-level competencies necessary for CAD system operation, and

2) rank these competencies in order of importance.

Methodology

Population. The population for this study consisted of all Iowa industrial personnel which were identified as currently using a computer aided design and drafting system. To determine the elements of the population, the researcher first identified CAD system suppliers from the literature. They were then contacted by phone to obtain the location of installations of their systems in Iowa. Personnel from the companies identified by the suppliers were then contacted by phone and the number of CAD system operators within the company was obtained. This number of instruments was then sent to the key person who was contacted to be distributed for completion, collection, and return.

Instrumentation. To develop an instrument, design and drafting skills were first compiled from textbook analyses, personal interviews, and CAD system brochures. Second, skills related to CAD system operation were added, as was a section to collect demographic information.

The instrument was then compiled by the researcher, reviewed by a panel of experts, modified, and sent to eleven respondents for pilot testing. A final revision was made following the return of ten instruments. The instrument was then printed and sent to 187 CAD system operators throughout Iowa.

Results

One hundred sixty-two (86.6%) useable instruments were returned. Of the fundamental drafting skills and concepts rated in the first section of the instrument, "geometric construction" received the highest ranking. "Mechanical assisted lettering" received the lowest rank.

The following items listed in rank order received rankings between a mean of 2 (Important) and 3 (Very Important): detail drawing, sectional views, assembly drawing, auxiliary views, use of line symbols, graphic rotation of views, coordinate dimensioning, spatial visualization, decimal dimensioning, descriptive geometry, drawing to scale, and third angle projection. Two items were rated as being "Not Important." They were: freehand lettering and mechanical assisted lettering. All other skills and concepts received a rating between 1 (Somewhat Important) and 2 (Important). In the second section of the instrument (related skills and experiences), "geometry" received the highest rating. "Trigonometry also ranked above 2 (Important). All other items were ranked between 1 (Somewhat Important) and 2.

The average length of time that CAD systems had been installed was 3.81 years, and the most commonly found system was manufactured by Computervision. Ninety-nine of the 162 respondents (61.1%) reported using a timesharing computer system, and the largest percentage (75.3%) of respondents used a minicomputer as opposed to the other two system types. One hundred twenty seven (78.39%) users reported having 2-dimensional capability. One hundred twenty nine responses (79.62%) indicated a lack of color capabilities. The same number responded as having an electrostatic plotter, while 53 (32.71%) used drum and 53 used flatbed plotters.

Discussion

The cover letter which was sent to key personnel in the various CAD departments contained a dime as an incentive to encourage return of the instruments. The percentage of returns was favorable (86.6%), yet the researcher believes that the phone contact which preceeded instrument mailing had a greater effect in achieving this goal.

The results of this study could serve as a guideline for Iowa educators and personnel involved with company training programs. The ranking of items on the instrument could be compared with current attention which is given to that item in the specific educational setting. Such comparisons would be of concern to industrial educators as well as those in other areas, such as math.

A top ranking of geometric construction indicates that educators who have computer aided design and drafting in mind should be concerned about this area. The results also indicate to industrial educators that there should not be an emphasis on mechanical assisted or freehand lettering.

The results of the second section of the instrument point out that there are other educational considerations which should also be made when instructing future CAD system operators (e.g., typing skills, math skills), as do responses listed in Appendix I. Ratings also showed that operators did not feel that entry-level CAD operators needed to have prior experience on a CAD system equal to the (hiring) firms. Since industries often spend hundreds of thousands of dollars on CAD systems, educational institutions will see this as a positive finding as they are generally tightly budgeted.

The large average number of CAD operators within a company indicates that there may also be a need to give more attention to communication skills to be used in relating to other CAD operators. Goetsch (1983) has concluded from a study of computer aided drafting skills that there is a similarity between manual techniques and CAD system techniques. This points to a need to compare manual techniques with CAD system operation since the use of CAD systems is so prevalent in society today. Also, because of this similarity, an explanation of how CAD systems carry out these functions should be included in the classroom. Along with this, benefits and applications revealed in the review of literature would indicate a need to explain these to the students.

The respondents of this study said that fundamental drafting skills are still important for CAD operators. Also, when rating freehand sketching very low, respondents may have been relating only to their involvement with sketching and not to the question of preparing future CAD operators.

The data concerning hardware which respondents were using gives educators an indication of what considerations should be made in teaching CAD. Since more than 90 percent of Iowa CAD systems have three dimensional capabilities, attention should be given to this in course instruction. On the other hand, color capabilities were only a part of slightly more than 19 percent of CAD systems. Electrostatic plotters are the most expensive of the three types mentioned on the instrument, yet their occurrence as a part of more than 79 percent of systems in use indicates a need for CAD educators to give a basic understanding of their operation. However, it must be pointed out that while the electrostatic plotter was a part of more than 79% of the systems in use, it was found primarily at John Deere and not in the smaller firms.

Several items concerning technical data (presented in Table 5) did not receive any response. This is likely because persons who checked one type of system, system capability, or plotter type may have left the other response spaces blank if they did not fit their situation.

Institutional or industrial educators should interpret the results of this study according to their specific setting. Current program needs and goals should be established prior to considering the results obtained from this survey of Iowa industries. A close look at the information provided in the third section should also give a clearer understanding of the responses in the first and second sections. A mainframe CAD system, for example, may have excellent ability to produce accurate lettering, thereby causing a lesser ranking of this item.

The acronym CAD (computer aided design and drafting) used in the instrument for this study could be intepreted in three ways. Some take it to mean computer aided drafting; others interpret it as computer aided design; and still others take it to mean a combination of both (the way in which it was used for this study). Therefore, the researcher did not define this acronym on the instrument, but let the operator respond according to their function.

Recommendations for Further Study

The following recommendations are directed towards two groups of people. The first set of recommendations is for the researcher, and the second set is for the practitioner.

Recommendations for the Researcher:

Further studies could be done in an effort to answer the following questions:

1) What is the correlation between entry-level competencies ranked in 1983 and competencies ranked in 1985?

2) What is the correlation between CAD system entry-level rankings by Iowa educators and rankings by industrial personnel?

3) What is the correlation between rankings of entry-level competencies made by CAD operators using different systems?

4) What is the correlation between rankings of competencies for CAD system operation and the number of years of experience which the respondent possesses?

Recommendations for the Practitioner:

The group of practitioners could be further divided into two categories. They would be: 1) CAD system operators, and 2) educators of future CAD system operators.

A) Recommendations for CAD System Operators:

1) Further training or research could be done by the operator in any area which is rated as being important to CAD system

operation.

2) Proficiency may be gained by CAD system operators by improving competency in the areas of related skills which were rated as being important.

B) Recommendations for the Educator of CAD System Operators:

1) Curriculum content could be examined to check for inclusion of competencies rated as important.

2) Attention could be shifted away from some areas currently emphasized in educational programs which received low rankings.

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Welsh, L. CAD/CAM - students - employees. Design News, 1982, 38(7), 96-101.

&Name&
&Title&
&Address&
&CityZip&

Dear &Name&:

Enclosed is the questionnaire which we have discussed by telephone. The information gained from it will be of significant value to educators and to industrial personnel.

The purpose of this study is to identify a number of skills and concepts which Iowa industrial personnel consider to be important and to determine their relevance in educating future computer aided designers and drafters.

Please examine the enclosed questionnaire, complete one yourself, and distribute the remaining copies to those CAD system operators which you feel can best respond.

If unavoidable circumstances prevent the return of completed questionnaires by March 18th, please return them as soom thereafter as possible.

I sincerely appreciate your help and consideration in this matter!

Many thanks,

Stephen Rockey
Project Supervisor

P.S. Accept this dime as a token of my appreciation and enjoy half of a candy bar while you pass out the forms!

University of Northern Iowa
Department of Industrial Technology
Cedar Falls, Iowa 50614

Important Entry-level Competencies for CAD System Operators

Directions: Below is a list of fundamental drafting skills and concepts. Please rate each item by circling whether you feel it is "Very Important"(3), "Important"(2), "Somewhat Important"(1), or "Not Important"(0) in preparing to become a CAD system user.

3	2	1	0	Instrument drawing (e.g., use of compass, T-square, triangles, templates)
3	2	1	0	Drawing to scale
3	2	1	0	Freehand sketching
3	2	1	0	Freehand lettering
3	2	1	0	Mechanical assisted lettering
3	2	1	0	3rd angle projection
3	2	1	0	1st angle projection
3	2	1	0	Use of line symbols (e.g., hidden, phantom, cutting plane)
3	2	1	0	Geometric construction (e.g., arcs tangent to lines)
3	2	1	0	Isometric drawing
3	2	1	0	Perspective drawing
3	2	1	0	Oblique drawing
3	2	1	0	Assembly drawing
3	2	1	0	Detail drawing
3	2	1	0	Sectional views
3	2	1	0	Auxiliary views
3	2	1	0	Construction of graphs and charts
3	2	1	0	Coordinate dimensioning
3	2	1	0	Decimal dimensioning
3	2	1	0	Fractional dimensioning
3	2	1	0	Metric measurement and dimensioning standards
3	2	1	0	Spatial visualization
3	2	1	0	Line quality (line weights, uniformity, etc.)
3	2	1	0	Graphic Rotation of views
3	2	1	0	Descriptive geometry
3	2	1	0	Grid line dimensioning
				Other: (please specify below or on back of sheet)
3	2	1	0	________________________________
3	2	1	0	________________________________

Listed below are some areas of skill and experience that are related to CAD. Please rate each item by circling whether you feel it is "Very Important"(3), "Important"(2), "Somewhat Important"(1), or "Not Important"(0) in preparing to become a CAD system user.

3 2 1 0	Computer programming
3 2 1 0	Typing
3 2 1 0	Matrix math
3 2 1 0	Algebra
3 2 1 0	Trigonometry
3 2 1 0	Calculus
3 2 1 0	Geometry
3 2 1 0	Prior experience with a CAD system equal to your firm's
3 2 1 0	Prior experience on a CAD system of any type
3 2 1 0	General computer knowledge
	Other: (Please specify below or on back of sheet)
3 2 1 0	______________________________
3 2 1 0	______________________________

In order to have a better understanding of the firms which are participating in this study, please complete the following items.

How many people does your firm employ ____________
How many of the firm's employee's are CAD operators? __________
How long has your firm's CAD system been installed?
What is the brand name of your system? ______________
Do you use time-sharing for CAD system? _____Yes _____No
Is your CAD system setup on a:
microcomputer ____ Yes ____ No
minicomputer ____ Yes ____ No
mainframe computer ____ Yes ____No
Does your CAD system have :
2-D capabilities ____ Yes ____No
3-D capabilities ____ Yes ____No
Does your CAD system have color capability? ____ Yes ____ No
Check the type of plotter your system uses:
____ Flatbed plotter
____ Drum plotter
____ Electrostatic plotter

If you would like a summary of the findings sent to you, please provide the name and address you would like them sent to.

Please return this questionnaire in the enclosed envelope by March 15th.

** THANK-YOU FOR YOUR HELP **

APPENDIX B

Periodicals Used to Identify CAD System Suppliers

Periodicals

Machine Design - 6/12/80; 2/10/83

Design News - 2/21/83

School Shop - 2/83

Computer Graphics World - 11/82

APPENDIX C

CAD System Suppliers

CAD system suppliers:

Applicon
32 Second Avenue
Burlington, MA 01803

Auto-trol Technology Corp.
Box 33815
Denver, CO 80233

Bruning
1229 First Avenue S.E.
Cedar Rapids, IA 52402

Calma
527 Lakeside Drive
Sunnyvale, CA 94086

Computervision
201 Burlington Road
Bedford, MA 01730

International Business Machines
1133 Westchester Avenue
White Plains, NY 10604

Keuffel & Esser
309 Era Drive
Northbrook, IL 60062

Rapids Reproductions
711 Second Avenue S.E.
P.O. Box 1087
Cedar Rapids, IA 52406

Tektronix Corporation
205-W Lakewood
Coralville, IA 52241

APPENDIX D

CAD System Supplier Contacts

Supplier contacts:

Mike Cox - Applicon

George Hansen - Computervision

John Kautenberger - Keuffel & Esser

Mike McGowan - Tektronix

Daniel M. McNeill - Auto-trol

Jerry Mohwinkle - A. M. Bruning

E. A. Piggot - Marketing Manager

Ronald Wasik - Rapids Reproductions

Casey Wiggins - Calma

APPENDIX E

Companies Identified to be Using CAD

Companies:

John Deere - Waterloo, Dubuque, Davenport

Collins Radio (Division of Rockwell) - Cedar Rapids

Square D - Cedar Rapids

Iowa Manufacturing (Division of Ratheon)

Alcoa - Davenport

J.I. Case - Bettendorf, Burlington

General Electric - Burlington

Positech - Laurens

Harnisfeger - Cedar Rapids

Fisher Controls - Marshalltown

Stanley Consultants - Muscatine

Sun Strand - Ames

A.D.M. (formerly Clinton Corn) - Clinton

Doerfer - Cedar Falls

APPENDIX F

Pilot Test Recipients

Recipients:

Dr. Ronald Bro
Department of Industrial Technology
University of Northern Iowa
Cedar Falls, IA 50614

Mr. George Hansen
Computervision Corp.
Cedar Rapids, IA

Mr. Loren Duchman
Department of Industrial Technology
University of Northern Iowa
Cedar Falls, Iowa 50614

Mr. Donald Riley
213 Mechanical Engineering Bldg.

University of Minnesota
Minneapolis, MN 55455

Ken Baskin
Deere & Co.
John Deere Rd.
Moline, IL 61265

Everett Williams
Physics Department
University of Iowa
Iowa City, IA 52240

Ronald Wasik

Cedar Rapids, IA 52406

Ronald Cozad
Doerfer Corp.
Cedar Falls, IA 50613

Tim Clark
Physics Department
University of Iowa
Iowa City, IA 52240

Donald Manor
Deere & Co.
John Deere Rd.
Moline, IL 61265

John Kautenberger
Keuffel & Esser Company

Northbrook, IL 60062

APPENDIX G

Company Personnel Who Were Contacted

and/or

Received the Instruments

Personnel:

Bob Barton - J.I. Case -- Bettendorf

Larry Thomas - J.I. Case -- Burlington

Jose Nazario - John Deere -- Dubuque

Diane Koester - John Deere -- Dubuque

Dave Robb - Catepillar -- Mount Joy

Richard Hileman - John Deere -- Waterloo, Product Engineering Center

Larry Kriener - John Deere -- Waterloo, Engine Works

Dan Teel - John Deere -- Waterloo, Components Works

Will Schawberger - Fisher Controls

Larry Wisor - Collins Radio

Arthur Stukey - Harnisfeger

Tom Mefferd - Positech

Noel Henneman - Stanley Consultants

Joe Grady - Square D

Dick Leabo - Alcoa

* Terry Smith - General Electric

* Dean Sanders - Sunstrand

* Paul Young - Doerfer

Wayne Letcher - A.D.M.

*These received no instruments because of the newness of their systems or because they were not carrying out computer aided design and drafting functions with their systems.

APPENDIX H

Number of Operators
Who Received the Instrument

Number of instruments sent; number of useable returns:

	# Sent	# Returned
Fisher Controls	20	17
Collins Radio	25	20
Harnisfeger	4	4
Positech	7	7
*John Deere (Component Works)	20	17
*John Deere (Engine Works)	10	10
**John Deere (Dubuque Works)	20	14
**John Deere (Dubuque Works)	10	2
John Deere (Product Engineering)	15	15
J.I. Case (Bettendorf)	10	9
J.I. Case (Burlington)	12	14***
Catepillar	1	1
A.D.M.	1	1
Stanley Consultants	16	16
Square D	6	6
Alcoa	10	10

* Instruments were hand delivered to these firms.
**Personnel from two different departments in this plant received instruments.
***Two (2) copies were made and returned.

APPENDIX I

"Other" Responses

Other responses:

<u>Section I</u> :

A sense of humor.

True position dimensioning.

Geometric dimensioning.

Basic computer knowledge.

Patience with any system.

Solid modeling for part definition.

Use of layering and/or color for assembly.

Detail visualization and manipulation.

Fundamentals of the design process (i.e. conceptualization -> layout -> detail); purpose of each phase & its relation to the manufacturing process.

Knowledge of mechanical drawing.

Understanding of the manufacturing practices as related to drawing symbols (surface finishes, bend radii, weld symbols, etc.)

Be able to communicate.

Exchange ideas.

Typing.

Three dimensional modeling.

Conversion of orthographic to isometric.

Conversion of isometric to orthographic.

Experienced draftsman.

Use of manuals; understanding of catalogue on filing systems.

"Other" responses: (continued)

Use of layers.

Drafting and dimensioning design standards.

X, Y, Z coordinates; axis of rotation.

Pre-planning (plan out work in advance).

Innovation.

Be able to read and understand wire frame "3-D" models.

Geometric tolerancing.

Company standards.

Ability to interpret engineering layouts.

<u>Section II</u>

Drafting training or experience.

All fundamental drafting skill should be familiar.

Computer needs exact information.

Willing to work flexible hours.

High level of patience.

System operation/management.

Graphic arts.

Logic or information theory.

Understanding of engineering setting to be worked in.

Language arts.

Understanding of system commands and usage of syntax.

Aptitude for computer interaction.