

The Required Knowledge and Skill Competencies for CAD and Design Engineering Students

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Abstract - Educators are challenged to upgrade course curricula and programs to meet industry needs; therefore they would like to hear from engineers to better achieve educational goals. Attention has been paid to identifying the knowledge and skill competencies required for college students who are going to apply for jobs in industry after graduation. Specifically, in order to align college outcome with the workplace demands, this study is to identify what knowledge and skills are required to empower Computer-Aided Design (CAD) and design engineering students to become successful in the workplace. A panel consisting of thirty engineers, designers and CAD professionals in the design engineering field participated in this study. These panel members were randomly selected from fifteen states in the United States. First, a brainstorming response was obtained from the panel members to identify the knowledge and skill competencies for successful CAD and design engineering students. Then, based on the response from the panel, a concentrated list of required knowledge and skills was proposed to the panel members for evaluation. Finally, a total of fifty required skills within six categories were identified and validated by the panel. The results provided valuable feedback from engineers for educators to more effectively prepare students with the knowledge and skills required to face today's challenges.

Index Terms - CAD, competencies, Delphi technique, design engineering, knowledge and skills

INTRODUCTION

Computer Aided Design (CAD) has been popular in the design and manufacturing industry since the early 1980's. Several studies reported the CAD revolution and drew attention to updating CAD engineering undergraduate education [1] – [3].

Responding to the needs of business and industry, CAD educational programs have been developed in post-secondary education. The intent of the programs is to imbue students with the required knowledge and skills to become technicians in industry. Duan [4] and [5] investigated CAD programs in public two-year colleges and indicated engineers can help educators upgrade programs.

Today millions of people are able to use CAD with personal computers. They can draw and design anything they desire. They can work in the office, in the classroom, at home or almost anywhere. The new development of CAD technology and engineering analysis is enabling engineers to

create and analyze design in a single process [6]. Obviously, the new design approach with CAD programs and engineering analysis requires designers and engineers to upgrade their knowledge and skills.

Throughout America in recent years, industrial experts and educators have been coming together to articulate educational goals that reflect convergence. Identifying the skills and competencies required for entry-level workers and college graduates was addressed in some studies [7 and 8].

In order to align college outcomes with workplace demands, the researcher of this study investigated what are the required knowledge and skill competencies for CAD and design engineering students.

METHODOLOGY

The researcher facilitated discussions with industrial CAD professionals in order to develop a list of required knowledge and skill competencies. A Delphi technique was used to collect data for this study.

The Delphi technique was developed by the Rand Cooperation in the 1950's, as an interactive process designed to query an interested group of experts and to reach a consensus of opinions on an issue. For example, a study about developing a unified curriculum framework for technical education using a Delphi technique was conducted by Wicklein and Rojewski [9]. Duan used a Delphi approach to develop a model curriculum for CAD degree programs and provided more details about the process [10].

A stratified random sampling method was used to identify the members for the CAD industrial experts' panel. The potential candidates were mainly selected from the Directory of the American Design Drafting Association [11]. Through communication and confirmation, a total of thirty members were finalized from fifteen states in the United States. The distribution of panel members by geographic location is shown in Table 1.

To investigate workplace demands, an initial well-designed instrument with 12 questions for the panel was sent to all the members to ask them for responses on this issue: What would best prepare CAD and design engineering students to be successful in the workplace?

A brainstorming response was received and collected. Then the researcher analyzed the response and developed a concentrated list.

On the second round, the list was sent to all of the panel members for their evaluation. A five-point Likert-type scale

was employed in the study to evaluate the list of required knowledge and skills. The criteria of numerical value were designed as follows: 5-Strongly agree, 4-Agree, 3-Moderately agree, 2-Disagree, 1-Strongly disagree. A mean value of 3.00 for an item means sixty percent of the panel members are in agreement, which is assigned to be used as criteria for consensus in this study.

The items with 3.00 and above would be validated, but those ones with below 3.00 will be dropped. As a result, a list of the validated required knowledge and skills is presented in this paper.

FINDINGS

Table 2 shows the breakdown of a total of 149 statements of knowledge and skills in the seven categories from the panel as the initial response. These categories include general knowledge and skills, interpersonal skills, basic drafting knowledge and skills, computer knowledge and skills, CAD knowledge and skills, basic engineering analysis and technical knowledge and skills, and special knowledge and skills needed in the field.

Based on an analysis and integration from the 149 statements, the researcher completed a list of 51 items of required knowledge and skills for the panel’s evaluation. The refined list concludes 11 items in general knowledge and interpersonal skills, 10 items in basic drafting knowledge and skills, 7 items in computer knowledge and skills, 6 items in CAD knowledge and skills, 10 items in basic engineering analysis and technical knowledge and skills , and 7 items in special knowledge and skills needed in the field.

TABLE 1

DISTRIBUTION OF PANEL MEMBERS BY GEOGRAPHIC LOCATIONS IN THE U.S.

Region	Number
Northeast	4
New York	3
Pennsylvania	1
Southeast	5
Florida	1
Maryland	1
Mississippi	1
North Carolina	1
South Carolina	1
Midwest	14
Indiana	6
Iowa	2
Michigan	3
Ohio	1
Wisconsin	2
West	7
Arizona	1
California	5
Utah	1
Total	30

The first category focuses on required general knowledge in English writing and speaking, communication, critical thinking, problem solving, mathematics, and science skills. In this category, Problem Solving ranks the first on the list with a

mean of 4.83. In turn, Communication with 4.62, Trigonometry with 4.59, Critical Thinking with 4.48, and Algebra with 4.45, are second, third, fourth, and fifth. Only Chemistry is the lowest with 2.97, which was not validated by the panel. Therefore, the other ten items were validated in this category. The rank and mean are indicated in Table 3.

TABLE 2
INITIAL FEEDBACK FOR REQUIRED KNOWLEDGE & SKILLS

Category	Number of Knowledge & Skills Statements by Category
General Knowledge & Skills	22
Interpersonal Skills	18
Basic Drafting Knowledge & Skills	27
Computer Knowledge & Skills	16
CAD Knowledge & Skills	23
Basic Engineering Analysis & Technical Knowledge & Skills	31
Special Knowledge & Skills Needed in the Field	12
Total	149

The second category is the required Basic Drafting Knowledge and Skills. Table 4 shows a total of ten items in this category. Basic Drafting with a mean of 5.00 is on the top of the list, while Basic Architectural Drafting is on the bottom with the mean of 4.07. However, all the items in this category were validated.

TABLE 3
GENERAL KNOWLEDGE & INTERPERSONAL SKILLS

Item No.	Required Knowledge & Skills	Mean	Rank
1	Algebra	4.45	5
2	Analytical Geometry	4.24	7
3	Trigonometry	4.59	3
4	Calculus	3.14	10
5	Physics	3.76	9
6	Chemistry	*2.97	11
7	Public Speaking	4.00	8
8	English Writing	4.38	6
9	Communication	4.62	2
10	Critical Thinking	4.48	4
11	Problem Solving	4.83	1
	*Disagree		

TABLE 4
BASIC DRAFTING KNOWLEDGE & SKILLS

Item No.	Required Knowledge & Skills	Mean	Rank
1	Basic Drafting	5.00	1
2	Descriptive Geometry	4.14	8
3	Technical Standards	4.41	3
4	Coordinates Systems	4.31	4
5	Multiview Drawings	4.45	2
6	Isometric Drawings	4.28	5
7	Geometric Dimensioning & Tolerance	4.14	8
8	Basic Mechanical Drafting	4.24	6
9	Basic Architectural Drafting	4.07	9
10	Basic Civil Drafting	4.17	7

The third category deals with required computer knowledge and skills. Table 5 shows the breakdown of this category with seven items. All the seven items were validated. Word Processing (4.79) is the top one, while Basic Programming (3.14) is the lowest one.

5	Troubleshooting Skills	4.31	3
6	Teamwork	4.59	1
7	Leadership Skills	4.52	2

TABLE 5
COMPUTER KNOWLEDGE & SKILLS

Item No.	Required Knowledge & Skills	Mean	Rank
1	Computer Fundamentals	4.31	3
2	Computer File Management	4.34	2
3	Word Processing (e.g. microword, word perfect)	4.79	1
4	Software on Windows for PC	4.00	4
5	Spreadsheets (e.g. excel)	3.93	5
6	Basic application of Internet	3.62	6
7	Basic Programming	3.14	7

TABLE 6
CAD KNOWLEDGE & SKILLS

Item No.	Required Knowledge & Skills	Mean	Rank
1	Major CAD Software	4.31	2
2	CAD 2D Drawings	4.52	1
3	CAD 3D Modeling	4.31	2
4	Basic CAD LISP Programming	3.34	5
5	CAD Design Project	3.97	3
6	Customization of CAD Program	3.69	4

Next, it is the category of the required CAD knowledge and skills in CAD software, 2D & 3D, and customization. All the six items have a mean higher than 3.00, as shown in Table 6. CAD 2D Drawings is most important, while Basic CAD LISP Programming is the last one.

The required engineering and related knowledge and skills are highlighted in the fifth category. Table 7 describes the category of Basic Engineering Analysis and Technical Knowledge and Skills. All the ten items were agreed on by the panel. The highest point is 4.66-Basic Engineering and Technology Terminology, but the lowest one is 3.62-Statics.

TABLE 7
BASIC ENGINEERING ANALYSIS & TECHNICAL KNOWLEDGE & SKILLS

Item No.	Required Knowledge & Skills	Mean	Rank
1	Manufacturing Processes	4.07	4
2	Statics	3.62	9
3	Materials Processing	3.69	8
4	Strength of Materials	4.07	4
5	Basic Measurement	4.62	2
6	Basic Engineering and Technology Terminology	4.66	1
7	Basic Machining	3.76	7
8	Basic Electronics	3.82	6
9	Basic Construction	4.28	3
10	Basic Surveying	4.00	5

The last category is about special needed knowledge and skills. All the seven items in the category of Special Knowledge and Skills Needed in the Field were agreed on by the panel. Teamwork ranks the first with 4.59, but Marketing and Sales takes the lowest with 3.07.

TABLE 8
SPECIAL KNOWLEDGE & SKILLS NEEDED IN THE FIELD

Item No.	Required Knowledge & Skills	Mean	Rank
1	Design Applications and Practices	4.52	2
2	Special Projects in the Field	4.10	4
3	Marketing and Sales	3.07	6
4	Basic Knowledge of Laws	3.41	5

CONCLUSION

The purpose of this study was to define a final list of the required knowledge and skills for CAD and design engineering students. As a result of the Delphi study, a total of fifty items for the required knowledge and skills in six categories were identified and listed in Table 9. Only one item was disagreed due to lower point. The list includes 10 items in general knowledge and interpersonal skills, 10 in basic drafting knowledge and skills, 7 in computer knowledge and skills, 6 in CAD knowledge and skills, 10 in basic engineering analysis and technical knowledge and skills, and 7 in special knowledge and skills needed in the field, respectively.

TABLE 9
SUMMARY OF VALIDATED REQUIRED KNOWLEDGE & SKILLS

Category	Number of Required Knowledge & Skills
General Knowledge & Interpersonal Skills	10
Basic Drafting Knowledge & Skills	10
Computer Knowledge & Skills	7
CAD Knowledge & Skills	6
Basic Engineering Analysis & Technical Knowledge & Skills	10
Special Knowledge & Skills Needed in the Field	7
TOTAL	50

The Delphi technique was used to obtain data and reach a consensus of opinions on the required knowledge and skills for industrial experts. Through two rounds in this Delphi process, a consensus for fifty items was reached. Finally, a list of the required knowledge and skills for CAD and design engineering students was validated by the panel of industrial experts. It was found that the Delphi technique was an appropriate and efficient research approach for this study, although time consuming.

The final fifty validated required knowledge and skills may be considered as indicators of requirements for successful CAD and design engineering students in their career. The results of this study enable educators to more effectively prepare students of CAD and design engineering with the required knowledge and skills for their successful employment, and also provide valuable feedback to the educational programs to align college outcomes and industrial demands.

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