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A Model Curriculum for Computer Aided Design (CAD) Associate Degree Programs

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Introduction

Computer Aided Design (CAD) is a good example of technological innovation that has had a significant impact on the design and manufacturing industry and other fields. The rapid pace of technological change requires responses and innovative approaches from institutions of higher education. Therefore, "the development of high-technology programs has become a major concern for post-secondary colleges across the country" since the early 1980s (Abram, Ashley, Hofmann, & Thompson, 1983, p. vii). Jeswiet and Surgenor (1985) conducted a survey to determine how industry feels about the technological progress and to seek advice on how to update educational programs. They concluded that an educational program "must continually adapt and upgrade its courses to remain in tune with the changing technology" (p. 41). Richards (1985) investigated the CAD/CAM revolution, and noted that, "Most American colleges and universities are struggling to catch up with developments in computer aided design and manufacturing" (p. 19). They "have to adjust to the new realities of education and devise innovative ways to meet the demands of their expanding constituency" (p. 24).

The early CAD educational programs appeared at the beginning of the 1980s. A significant trend was to introduce CAD into traditional drafting curriculums and upgrade the programs. "The availability of micro-computers with their ever increasing capabilities at affordable prices has given educators an opportunity and a challenge" (Audi, 1987, p. 22). Isabell and Lovedahl (1988) indicated that, "The proliferation of micro-CAD has placed virtually every post-secondary drafting program into the position of being able to introduce students to CAD" (p.13).

The number of CAD users rapidly increased after more CAD systems were provided. At the end of the 1960s, only 200 workstations were operating at large aerospace and automotive companies and governmental laboratories in the United States. However, the number of users started to climb and was estimated to be more than twenty-five thousand in 1983 (Abram, et al, 1983). CAD software producers have upgraded and created many new CAD software packages to support educational institutions and to meet the needs of business and industry. Today, millions of people are able to use CAD with personal computers. As a worldwide design resource and software producer, Autodesk Company has helped over 4,000,000 professionals for their designs in over 160 countries using its products (*AutoDesk Worldwide*, 2002).

Educators have responded to the changing technology. By the end of the last century, CAD programs were available in American higher education, as well as in post-secondary education in many countries throughout the world. In the United States, several hundred two-year colleges offered CAD associate degree programs in manufacturing and construction fields (Gabriel, 1998).

Hill (1993) conducted a study about the impact of CAD on both the apparel industry and college apparel design

program in Quebec, Canada. Hill sought to determine what knowledge and skills were needed of apparel designers to be successful in the workplace with CAD technology, and how corresponding college programs assisted students to understand and use CAD technology. According to the result of the study, Hill noted that, "This study needs to be replicated both in other provinces and countries and in other professional fields where college programs correspond to the world of the work" (p. 249).

Wicklein and Rojewski (1999) addressed curriculum framework for technology education. Curriculum that emphasized technical content tended to be rather short lived and was constantly changing due to the rapid accumulation of knowledge and techniques used in business and industry. They encouraged "a dialogue about the possibility and desirability of identifying a basic, unifying force for curriculum planning in technology programs" (p. 41).

Duan (2003) reviewed the history of CAD program development and the literature on CAD programs in public post-secondary education. Duan noted that, "To respond to the needs of business and industry today, community colleges have developed CAD programs for students. However, there are a limited number of research studies that have sought to investigate how well students' preparation at community colleges aligns with the needs of business and industry"(p.4).

In order to align community college outcomes with workplace demands, it would be logically follow to conduct a nationwide investigation with college CAD programs and the needs of business and industry. Specifically, a study is to investigate what community colleges are teaching for CAD associate degree programs and what knowledge and skills are required to empower CAD students to become successful in the workplace.

Purpose

Today, rapid technological development requires innovative educational approaches. Little research has been done to inform curriculum and content decisions in CAD programs at community colleges; this implies that what is currently taught may not match the needs of business and industry. Therefore, the purpose of this study is to determine how CAD associate degree programs at the community colleges could provide an ideal curriculum for students. In order to better meet the needs of business and industry, a model curriculum for CAD associate degree programs would be developed and proposed.

Methodology

A Delphi technique was used to collect data from CAD professors at community colleges and industrial CAD professionals. The researcher of this study facilitated discussions between college CAD professors and industrial CAD professionals to bring consistency between community college students' preparation and the needs of business and industry. The Delphi technique was developed by the Rand Corporation in the 1950's, and has been used extensively in education settings. This technique is an interactive process designed to query an interested group of experts assembled around a specific topic for the purpose of reaching a consensus of opinions on issues related to that topic. The Delphi technique is a good approach to elicit and refine the opinions of a group of people. The process is repeated for several rounds until the investigator obtains positions that are firm and an agreement on the topic is reached.

The Delphi technique may be modified in many ways (Brooks, 1979; *Delphi technique*, 1994; Pullen, 19 96, Smallwood, 1988). There are the following steps in the study:

1. Identify the Two Panels of Experts

Selecting qualified participants as members of the two panels was critical to this study. Each member of the Panel of Industry Experts has to be a professional from business and industry such as a designer, drafter, engineer, architect, manager or supervisor in the related field with a minimum of three years of industrial experience. Each member of the Panel of Institution Experts has to be a community college CAD professor, such as a chairperson or faculty member, at an accredited public two-year college and with a minimum of three years of teaching experience at the college level.

A stratified random sampling method was used to select the potential candidates for both panels to ensure geographic representation. The potential candidates for industry experts were mainly selected from the *Directory of the American Design Drafting Association* (*ADDA*, 2000); the potential candidates for institution experts were selected from the *Directory of Two-Year Program* (*NAIT*, 1998) and the *Directory of Public Vocational-Technical Schools, Colleges, and Institutes in the U. S. A.* (Gabriel, 1998).

A panel of the first fifty selected candidates in each group was contacted via telephone, mail, fax, and e-mail. If a selected candidate was not willing to participate, another candidate in the same region was randomly chosen, and this new person was contacted. If a selected candidate was willing to participate and met the requirements, this candidate became an official panel member upon the return of the completed questionnaire. The process continued until each of the two panels contained at least thirty members, and was then finalized. In this study, all 62 members were from 29 states in the United States.

During the initial phase of identifying the two panels, a total of 149 official invitations were mailed to the potential industrial candidates and a total of 133 official invitations were mailed to the potential institutional candidates. The ratio of their acceptance in participating in this Delphi study is shown in Table 1.

2. Surveying College CAD Programs and Eliciting Catalogs
In order to better understand community college students' preparation and needs of business and industry, the necessary information was requested for all panel members. To investigate community college CAD programs, an initial instrument with 18 questions for the Panel of Institution Experts was designed. Meanwhile, all the members of Institution Experts were requested to provide their curriculum catalogs.

3. Surveying CAD Professionals in Industry and Eliciting Opinions
To investigate workplace demands, an initial instrument with 12 questions for the Panel of Industry Experts was designed. In addition, all the members of Industry Experts were required to provide individual brainstorming response on this issue: What would best prepare CAD associate degree students to be successful in the workplace?

4. Evaluating the List of Required Knowledge and Skills
An analysis of the feedback from industry experts and necessary curriculum information from the institution catalogs was conducted. The data from both panels were combined and merged to form a list of the required knowledge and skills for the evaluation of the two panels.

5. Developing a Model Curriculum
Based on an analysis of data of required knowledge and skills, the validated items of required knowledge and skills must be key elements in a proposed model curriculum. This proposed model would be subsequently sent to two panels for their evaluation.

6. Validation of the Model Curriculum
Based on the results of the prior Delphi study, a mean value of 3.00, which indicates sixty percent of the panel members are in agreement, was assigned to be used as criteria of consensus. In addition, a five-point Likert-type Scale was employed to evaluate the list of required knowledge and skills, and the proposed model

Table 1. Ratio of Acceptance of Invitation to Participate in This Study

	Industry Experts Panel	Institution Experts Panel
Number of mailed invitations	149	133
Number of confirmed acceptance	30	32
Percent of acceptance	20.13%	24.06%

Note: *In addition to the official mailed invitations, the researcher also conducted many invitations to candidates through the telephone, e-mail, and fax.*

Table 2. Characteristics of Panel Members by Highest Degree Held

	Panel of industry experts		Panel of institution experts	
Degree	Number	Percentage	Number	Percentage
Doctorate			4	12.50%
Master	6	20.00%	17	53.13%
Bachelor	5	16.67%	7	21.87%
Associate	15	50.00%	4	12.50%
Other*	4	13.33%		

**Note: "Other" indicates as follows:* *High school diploma 2*; *Drafting & design certificate 1*; *Not specified 1*

Table 3. Characteristics of Panel of Institution Experts by Position Title

	Position	
Title	Number	Percentage
Dean	1	3.12%
Chair	11	34.38%
Program Head	1	3.12%
Program Director	1	3.12%
Program Coordinator	1	3.12%
Faculty	17	53.13%
Total	32	100%

	Academic Rank	
Title	Number	Percentage
Professor	5	15.62%
Associate Professor	6	18.75%
Assistant Professor		
Instructor	21	65.63%
Total	32	100%

curriculum. The numerical values are as follows: 5—Strongly Agree, 4—Agree, 3—Moderately Agree, 2—Disagree, 1—Strongly Disagree.

Findings

1. General Description of Participants

Tables 2, 3, 4, and 5 show characteristics of panel members by highest degree held, position title, and years of experience, respectively. The demographic data indicated that all panel members have significant experience. The panel of Institution Experts has an average 17.47 years of teaching experience; all members have industrial experience with an average 8.91 years. Nearly forty-seven percent of members are chairs, 53.13% are faculty members. Over thirty-four percent of members are Professors and Associate Professors. In the Panel of Industry Experts, 26.67 % of members are designers, 20% are engineers, 16.67% are managers, 10% are supervisors, and 6.66% are technicians.

2. College Course Offerings

The catalogs from all the surveyed colleges were collected, with 68.75% of catalogs obtained over the Internet and 31.25% mailed directly by the participants. A total of 174 courses were identified from the submitted course curriculum catalogs, and listed in the categories of general education courses, support courses, technical core courses, and specialty courses (see Table 6).

3. Feedback from Industrial Experts

Table 7 provides the summary of feedback from the Panel of Industry Experts with a total of 149 items that relate to the required knowledge and skills. Especially, these 149 items are included in the seven categories: 1) General knowledge and skills, 2) Interpersonal skills, 3) Basic drafting knowledge and skills, 4) Computer knowledge and skills, 5) CAD knowledge and skills, 6) Basic engineering analysis and technical knowledge and skills, and 7) Special knowledge and skills needed in the field.

4. Required Knowledge and Skills for CAD Students

Table 4. Characteristics of the Panel of Industry Experts by Position Title

Position	Number	Percentage
Engineer	6	20.00%
Designer	8	26.67%
Technician	2	6.66%
Drafter	1	3.33%
Manager	5	16.67%
Supervisor	3	10.00%
Other *	5	16.67%
Total	30	100%

**Note: "Other" specifies as follows:*		
	Drafting Coordinator	*1*
	Owner	*1*
	Owner/President	*1*
	Research & Development Specialist	*1*
	Technical Support Specialist	*1*

Table 5. Characteristics of two panels by Years of Experience

	Institution Experts Panel	Industry Experts Panel
Teaching		
Average	17.47	
Range	3—35	
Total	559	
Industrial		
Average	8.91	23.23
Range	1—30	3—55
Total	285	697

Table 6. Classification of Course Offering

Categories		Number of Courses by Category
General Education		32
Support Courses		8
Technical Core Courses		51
Specialty Courses		83
Mechanical Specialty	31	
Architectural Specialty	17	
Civil Specialty	17	
Other Specialties	18	
Subtotal	83	
Total		174

Based on the information from 174 courses taught at colleges and 149 items of required skills and skills from industrial experts, a list of 51 items of required knowledge and skills were created and sent to all the members of the two panels for their evaluation. As shown in Table 8, only 47 items were validated by the two panels. All 47 items have a mean higher than 3.00. Only four items had a mean less than 3.00, so that they were not validated. These items were Calculus, and Chemistry, in the category of General knowledge and skills; Marketing and Sales, and Basic Knowledge of Laws in the category of Special knowledge and skills needed in the field. As key elements, these 47 validated items are emphasized in the process of development of a model curriculum.

Implications

At the last stage of the Delphi process, a proposed model curriculum for CAD associate degree programs was sent to all the members of the two panels for their evaluation. Based on their evaluation, the Likert-type Scale mean for the Panel of Institution Experts is 4.34, and the mean for the Panel of Industry Experts is 4.61. Both group means were higher than 3.00, thus validating the proposed model curriculum. Therefore, the validated curriculum became an ideal model curriculum for CAD associate degree programs. Table 9 shows the proposed 24 courses for a CAD curriculum.

In order to meet today's business and industry needs, the model curriculum was developed. The intent of the model curriculum is to prepare students to become technicians specializing in manufacturing and construction areas. The model curriculum provides competency in CAD technology programs for students who desire employment in the drafting and design fields upon graduation. Technicians use mathematics, science, and engineering to solve technical problems in the field. This requires creativity, good communication skills, and the ability to work with others. Especially, technicians are required to be competent with CAD systems.

Table 7. Category of Required Knowledge and Skills Identified from the Feedback

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

Table 8. Results of Validation for Required Knowledge and Skills

Category	Number of Items on the list for evaluation	Number of Items validated by the two panels
General Knowledge and Skills	6	4*
Interpersonal Skills	5	5
Basic Drafting Knowledge and Skills	10	10
Computer Knowledge and Skills	7	7
CAD Knowledge and Skills	6	6
Basic Engineering Analysis & Technical Knowledge and Skills	10	10
Special Knowledge and Skills Needed in the Field	7	5*
Total	51	47

**Note: In the category of General Knowledge and Skills, Calculus and Chemistry were not validated. In the category of Special Knowledge and Skills Needed in the Field, Marketing and Sales and Basic Knowledge of Laws were not validated.*

The purpose of support courses is to enhance student's ability and skills in microcomputer applications, interpersonal communications, and technical writing. Next, the purpose of technical core courses is to provide a necessary training for students in drafting, CAD concept and application, manufacturing process, and engineering analysis. This category includes seven courses that are required for all CAD students.

After completion of support courses and technical core courses, CAD students are ready to take specialty elective courses. Though a variety of specialties within CAD programs exist at community colleges, it was found that Mechanical, Architectural, and Civil specialties are the most popular for CAD programs (Duan, 2003). For this reason, only these three specialties were suggested in the curriculum.

The technical elective courses provide more options for students in technical training. Five courses are arranged in this category, each one could be applied to any specialty with a specific focus. For example, the focus is to enhance student's CAD ability, knowledge of the latest standards, and creation of student's portfolio.

As a core curriculum, the list of 24 courses in four categories in Table 9 provided brief descriptions. In addition to the core curriculum, several suggested general education courses are also listed in the note portion of the table. Therefore, a combination of general education courses and the core curriculum is offered to students as a deliverable approach for a two-year associate degree. However, adjustments may be necessary to accommodate general education courses and the core curriculum courses for an individual institution in the delivery process to better serve students.

Conclusion

As an example of technological innovation, CAD is widely used in the design and manufacturing industry. In order to meet the needs of business and industry today, a model curriculum for CAD associate degree programs at community colleges was developed. In this Delphi study process, a total of 62 participants were selected randomly from 29 states in the United States. Thirty members in the industry experts' panel and thirty-two members in the institution experts' panel contributed their ideas, experience, and expertise to develop a model curriculum.

In summary, both panels, with a Likert-type Scale mean of higher than 3.00, reached a consensus for the proposed model curriculum. This validated curriculum model, with 24 courses in 3 suggested specialties, provides a combination of a solid theoretical foundation, classroom studies, and laboratory practice for CAD associate degree students. This model curriculum could be beneficial to students, educators, prospective employers of industry, and society at large.

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Table 9. A Validated Course Curriculum for CAD Associate Degree Programs

Number/Course Title	Brief Description
Support Courses:	
1. **Microcomputer Applications**	Introduction to microcomputer hardware, software, applications, and computer literacy.
2. **Interpersonal Communications**	Applying interpersonal communication theory for work, family, and social relations.
3. **Technical Writing**	Preparing technical reports for various purposes.
Technical Core Courses:	
4. **Engineering Graphics**	Introduction to drafting applications at proficient technician level, including drafting tools and various drawings.
5. **Descriptive Geometry**	Introduction to fundamental principles in developing graphic solutions to engineering problems.
6. **CAD Fundamentals**	Introduction of concepts and skills for 2D computer-aided drafting and design.
7. **Advanced CAD**	Introduction to CAD advanced features and 3D modeling.
8. **Manufacturing Processes**	A basic survey of manufacturing process, tools, techniques, and equipment.
9. **Applied Statics**	Study of applied mechanics dealing with bodies at rest.
10. **Strength of Materials**	Study of internal stresses, physical deformation and mechanical properties of materials.
Specialty Elective Courses:	
	Mechanical Specialty
11. **Mechanical Drafting**	Introduction of concepts for both detail and assembly working drawings.
12. **Tool Design**	Focus on tooling, location, supports, holding devices, and clearances.
13. **Mechanical Design Project**	Study of machine elements and practical solutions to mechanical design problems.

Table 9. A Validated Course Curriculum for CAD Associate Degree Programs

Number/Course Title	Brief Description
	Architectural Specialty
14. **Architectural Drafting**	Focus on architectural drafting of commercial or residential buildings.
15. **Building Codes and Standards**	Providing technical information and standard code.
16. **Architectural CAD**	Application of advanced CAD methodology and latest standards in architectural drafting, design, and construction.
	Civil Specialty
17. **Civil Drafting**	Study of civil drafting, design practice, and preparation in civil engineering industry.
18. **Fundamentals of Surveying**	Introduction of survey concepts, equipment and procedures.
19. **Structural Drafting**	Focus on detailing commercial structural members, connections and methods of construction.
	Technical Elective Courses:
20. **CAD Programming and Customizing**	Focus on advanced features of CAD, including customizing and Auto Lisp programming.
21. **Geometric Dimensioning and Tolerancing**	Introduction of fundamentals and the latest ANSI standard.
22. **Technical Standards and Terminology**	Introduction to latest standards and terminology in engineering and technology.
23. **Special Projects**	Study of special problems, such as software, engineering topic, or a project not covered in previous course.
24. **Portfolio Development**	Focus on the student's final portfolio for graduation and job interview.

**Note: Suggested General Education courses: Fundamentals of Public Speaking, English Composition, College Algebra, Geometry/Trigonometry, Physics, and Social/Humanities Elective.*