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ABSTRACT

The current status of computer-aided manufacturing in the 4-year industrial technology programs in the United States was studied. All industrial technology department chairs were mailed a questionnaire divided into program information, equipment information, and general comments sections. The questionnaire was designed to determine the subjects being taught, the sequence and content of courses, the equipment and programs used in teaching, and limiting factors in teaching computer aided manufacturing. The 124 returned questionnaires represented over three-fourths of the industrial technology programs in the country. Eight of 10 responding institutions offer computer-aided manufacturing, and more than half of these offer a sequence of courses. On average, each department uses two to three computer numerical control machines, and many different kinds of software are used. No one factor is a significant inhibitor of teaching computer aided manufacturing. Nine tables present study findings. (Contains 6 references.) (SLD)

National Survey of Computer Aided Manufacturing in Industrial Technology Programs

Paper Presented at the
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by

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INTRODUCTION

Computer Automated Manufacturing (CAM) is a concept that is used to describe the general category of advanced approaches to manufacturing. CAM employs many modern manufacturing technologies, such as computer aided drafting (CAD), computer numerical control (CNC), and robotics. These technologies which are involved in CAM are making complex processes and automated factories a reality (Powers, 1990; Shaw, 1993).

The introduction of CAM in manufacturing is a major area of technology that has revolutionized American industry. Some of the benefits of computer automated manufacturing to industry include: reducing time to make prototype parts; significantly easier advanced 3-D surface cutting; and one system to program and control machinery. The increasing demand for tighter tolerances, better quality consistency, reducing scrap, and the need for more output per machine and worker hour have made CAM an economic necessity for today's industry (Hall, 1992). The need for improved machines, and skilled operators which are comfortable with the definition and operation of CAM is a necessity (Voice, 1988). Ardayfio (1989) suggests that in spite of these developments, appropriate training in CAM has been found to be somewhat lacking and behind the level of practice in industry.

The importance of CAM in today's industry has promoted many industrial technology programs across the country to implement and teach CAM in their curriculum (May, 1990). The presentation

of a broad spectrum of CAM in industrial technology programs should provide the necessary information to present the existing level of CAM offerings in industrial technology programs across the United States. Many industrial technology programs have successfully integrated CAM technologies into their curriculum. However, no concerted effort has been made to determine the extent to which these programs have implemented CAM technology and identify the sequence of classes, or the status of existing hardware and software being utilized in these programs.

In the last year other studies have been conducted dealing with automated technologies in industrial technology programs (Shaw, 1993). However, a national study of CAM technology has not been conducted that provides numerical data regarding the number of machines, sequence of classes, or the kind of software being used in teaching of CAM. Therefore, this study was designed to fill that void, and to supply educators in industrial technology programs and industry with the necessary information about computer automated manufacturing that dictate training and subsequent use of this technology in preparing and delivering instruction. The information reported will serve as a base from which meaningful decisions can be made and upon which future studies can be designed and conducted.

Purpose and Objectives of the Study

The purpose of this study was to investigate the current status of computer aided manufacturing in four-year industrial technology programs in United States. All industrial technology department chairs were mailed a research questionnaire. The

study was divided into the following three categories: program information, equipment information, and general comments and was designed to answer the following questions which served as the basis for conducting the study:

1. Which subjects are being taught in the manufacturing area of industrial technology programs?
2. What subject sequence and course order is evident in the manufacturing area of industrial technology programs?
3. What type of CAM equipment is utilized in existing industrial technology programs?
4. What kind of software programs are being used for teaching CAM in industrial technology programs?
5. What factors, if any, significantly limit the ability of professors in the teaching of computer aided manufacturing?

METHODS AND PROCEDURES

Over View of the Study

This project was conducted in two phases. The first phase involved a brief review of literature, as well as the development and pilot testing of the survey questionnaire. The questions used in the survey instrument were developed from the objectives of the study in the three categories described in the purpose and objectives section. The second phase included the mailing of the questionnaire, collection, analysis, and reporting of the collected data.

Population and Survey Instrument

The population for the study included all industrial technology program chairpersons in the United States. Chairpersons from all the industrial technology departments were invited to participate in the study. Each department chair was mailed a copy of the questionnaire and a cover letter explaining the nature of the study. All solicited respondents were asked to return the completed instrument within four-weeks after it was received. Those department chairs not returning the completed survey instrument were mailed a second request approximately four-weeks after the first mailing.

Data Collection and Analysis

All data collected was based upon respondents answers to questions in the survey instrument, (See Appendix 1) utilizing a variety of reporting formats. The survey questionnaire used in the study requested that respondents fill-in information in parts I and II. Question number nine in part II required the selection of a number response on a Likert-type scale. All data was compiled and reported in tabular format.

The analysis of data included the computation of a percentage scores reported for each entry. A listing of all fill-in information was tabulated and reported as received.

A discussion of all data based on tabulated information is reported in the next section. Results of the information received in this investigation are presented, as well as implications and recommendations for further study.

PRESENTATION AND DISCUSSION OF DATA

I. Program Information

Demographic Information

All industrial technology program chairpersons listed in the industrial technology baccalaureate program directory were mailed the survey questionnaire. A total of 156 industrial technology program chairpersons were mailed the first round of the survey questionnaire. Of those mailed, 82 (52%) were returned. Approximately four-weeks later, a second round was mailed with 42 (30%) returned. Total survey questionnaires returned numbered 124 or (82%), representing over three-fourths of the industrial technology programs in the United States. The research designed included frequency distribution analyses of reported information from industrial technology program chairpersons responding to the questionnaire which is illustrated in table 1.

TABLE 1

Frequency Distribution of Chairpersons Responding to the Survey Instrument

	N	Round #1	Round #2	Total
IT Programs	156	82(52%)	42(30%)	124(82%)

CAM in Industrial Technology Programs

Question number 1 requested information about IT programs which offer computer aided manufacturing. Of the 124 respondents, 79% or 98 programs offered computer aided manufacturing, while 21% or 26 programs did not offer courses or a program of study in computer aided manufacturing. Question number 1 was divided into two parts, the second part asked when CAM technology had been implemented in their respective programs.

TABLE 2

Number of Years That CAM Has Been Implemented in IT Programs

Number of Years	Frequency	Percent
Less Than Five Years	32	26%
Five to Ten Years	45	36%
Over Ten Years	14	11%
No Program or No Response	33	27%

Table 2 identifies the number of years that CAM technology has been implemented in IT programs. Eleven percent have had programs in place for over ten-years, while 36% have been in place five to ten-years, and 26% have been implemented in the last five-years.

Average Student Enrollment

Table 3 indicates the average student enrollment in CAM and

manufacturing classes in industrial technology programs. Ninety nine industrial technology programs responded to this question. thirteen percent or 13 reported enrollment of less than 10, 36 percent or 36 programs reported enrollment of 10 to 15 students, 42 percent or 41 responded that 15 to 25 students enrolled in CAM and manufacturing programs, and 9 percent or 9 indicated enrollment of 25 to 30 students.

TABLE 3

Average Student Enrolment in CAM and Manufacturing Courses

Average Enrollment	Frequency	Percent
Less Than 10	13	13%
10 to 15	36	36%
15 to 25	41	42%
25 to 30	9	9%

Total Number of CAM and Metal Working Courses

When asked to respond to question number 4, "Total Number of Classes Offered Related to Metal Working and CAM", 63% or 61 programs indicated 5 or less classes, 34% or 33 departments answered 6 to 10 classes were being offered that relate to CAM and metal working, and 3% or 3 programs responded that they offer over 10 classes. Table 4, presents the number of courses in CAM and metal working technology currently offered in industrial technology programs.

TABLE 4

Total Number of Courses Related to Metal Working and CAM

Number of Courses	Frequency	Percent
5 or Less	61	63%
6 to 10	33	34%
Over 10	3	3%

Courses Being Offered in Industrial Technology Programs

Question number 5 presented a list of courses and requested that respondents check the courses that are currently being offered in their industrial technology programs. Of the 124 total responses 68 or 55% offered introduction to metals courses, 100 or 81% offered manufacturing processes courses, 80 or 64% offered machine tool courses, 82 or 66% offered CAD/CAM courses, 40 or 32% taught cell manufacturing courses, and 31 or 25% offered flexible manufacturing systems courses. Table 5 presents the information obtained about current manufacturing courses being taught in industrial technology programs.

TABLE 5

Manufacturing Courses Being Offered in Industrial Technology Programs

Course	Frequency	Percent
Introduction to Metals	68	55%
Manufacturing Processes	100	81%
Machine Tool	80	64%
Computer Numerical Control	84	68%
CAD/CAM	82	66%
Cell Manufacturing	40	32%
Flexible Manufacturing Systems	31	25%

Sequence of Subjects Being Taught in the Manufacturing Area

In this part of the survey, the department chairs of industrial technology Programs were asked to identify the sequence of manufacturing courses that are being offered in the programs. The respondents were given a list of classes and asked to check in numerical order the subjects being taught in the manufacturing area of their IT Program. Table 6 shows the sequence of classes reported. Fifty-three percent offer introductory and advanced machining courses that include CNC, CAD/CAM, cell manufacturing and flexible manufacturing, while 39% offer introductory and advanced machining, and include only CNC and CAD/CAM courses. Eight percent are offering only

introductory and advanced machine tool courses.

TABLE 6

Sequence of subjects Being Taught in the Manufacturing Area of IT programs

Sequence of Courses	Frequency	Percent
Introduction and Advanced Machine Tool Courses	8	8%
Introduction and Advanced Machining Plus CNC and CAD/CAM Courses	41	39%
Introduction and Advanced Machining Courses Plus CNC, CAD/CAM, Cell Manufacturing and Flexible Manufacturing Courses	56	53%

II. Equipment Information

CAM Equipment Currently Utilized in IT Programs

This section of the study determined what types of CNC machinery was used in industrial technology programs (i.e. Desktop control by personal computer, Industrial type control by personal computer, Desktop control by panel, and Industrial type control by a panel) . The total number of CNC machinery reported in use was 282 with 133 machines being CNC lathes and 149 being CNC milling machines. Numerous brands of

CNC machinery were listed in the survey. The various CNC machinery types being used in IT programs and their respective frequency distributions are illustrated in table 7.

TABLE 7

CAM Equipment Utilized in Industrial Technology Programs

Type of Machinery	Number of Machines
Desktop Lathe Controlled by Personal Computer	57
Desktop Mill Controlled by Personal Computer	49
Industrial Lathe Controlled by Personal Computer	20
Industrial Mill Controlled by Personal Computer	38
Desktop Lathe with Control Panel	25
Desktop Mill with Control Panel	16
Industrial Lathe with Control Panel	31
Industrial Mill with Control Panel	46

Location of CAM Equipment

When was asked about a specific location for housing CNC machinery, 26 or 50% of the respondents indicated that a separate designated CAM Laboratory housed all of their CNC machines. The remainder indicated that their CNC equipment is housed with other metal working machinery in joint usage laboratories.

Software Programs Used for Teaching CAM

Question #8 deals with different kinds of software programs

available for use in teaching CAM. Mastercam and Smartcam were reported most frequently as the preferred choice of those responding. This suggests that industrial standard CAM software is preferred for instruction among educators in IT programs. However, educational software such as; Spectralight, D & M, and Dyna were used in some programs. Table 8 identifies software currently used in industrial technology programs.

TABLE 8

Software Programs Used for Teaching CAM

Software Available	Frequency
Mastercam	40
Series 1400 CNC Control	2
Spectralight CAD/CAM Software	13
D & M CAD/CAM Software	13
Dyna CAD/CAM Software	12
Emco Software	3
Smartcam	15
Others (Easycam, EZmill, Cimcam, Powercam, Cutting Edge, Mazak, Numeridex)	17

Some industrial technology programs reported using more than one brand of CAM software.

Factors Significantly Limiting the Teaching of CAM

Question number 9 dealt with the items that professors felt limited their ability to teach CAM in industrial technology programs. These factors included availability of equipment (ie, budget, cost, and funding), availability of software, lack of training, lack of student interest, and lack of student background.

A likert-type scale was used to collect the data. The most significant factor identified as limiting the teaching of CAM, with the average of 3.8, was the availability of CNC equipment. The least significant factor identified, with mean of 1.6, was the lack of student interest. The availability of software is the second most significant factor limiting the teaching of CAM in industrial technology programs. Lack of student background and lack of training have means of 2.3 and 2.7 on a scale of 1 to 5. Table 9 graphically illustrates the data and the calculated means of the responses to this question.

TABLE 9

Factors that Industrial Technology Professors Felt Significantly Limiting Their Ability to Teach CAM

Statement	Responses					Total	Responses X
	Least Significant				Most Significant		
	1	2	3	4	5	Total	X
Availability of CNC Equipment	7	12	10	21	38	89	3.8
Availability of Software	15	12	20	20	22	89	3.25
Lack of Training	22	17	21	14	10	84	2.7
Lack of Student Interest	50	16	6	7	0	79	1.6
Lack of Student Background	33	16	18	11	5	83	2.3

IMPLICATIONS OF THE STUDY

This study was designed to investigate the extent to which computer aided manufacturing technologies have been implemented in industrial technology programs nation wide. The implications section is divided into the five questions derived from the purposes and objectives section of the study. In the following narrative each question is examined and discussed according to formulated results obtained in this investigation.

Question #1 Which subjects are being taught in the manufacturing area of industrial technology programs?

Results reveal that eight-out-of-ten industrial technology programs offer computer aided manufacturing. The majority of CAM programs in the United States have been implemented during the last ten-years. This fact demonstrates the emergence of CAM as a viable means of production in the manufacturing sector during the past ten-years. A majority of industrial technology programs offer five classes to fulfill the manufacturing requirement of their curriculum. More than half of the industrial technology programs surveyed offer courses related to introductory and advanced machine tools, as well as upper division courses related to CNC and CAM. About one-third of industrial technology programs reported that cell manufacturing and flexible manufacturing systems courses are included in their curriculum. Since most industrial technology programs efforts include updating instructional methods which reflect industrial practices in their curricular offerings, the trend suggests the need for more course offerings in the manufacturing automation area. This includes courses related to robotics, cell manufacturing and flexible manufacturing systems.

Question #2 What subject sequence and course order is evident in the manufacturing area of industrial technology programs?

It is important to mention that sequence and quantity of courses related to a particular subject, indicates the emphasis of the educational establishment regarding that subject. Almost

all of the industrial technology programs surveyed offered a sequence of courses from introductory to advanced which related to conventional machine tools, with great emphasis put on CNC and CAD/CAM courses. The sequence of courses offered, also includes manufacturing processes. More than half of all industrial technology programs offer a composite sequence of computer manufacturing courses. The sequence included introductory and advanced machine tool courses plus CNC, CAD/CAM, cell manufacturing, and flexible manufacturing courses.

Question #3 What type of CAM equipment is utilized in existing industrial technology programs.

A variety of CNC mill and lathe equipment, both industrial and educational models, are being used by industrial technology programs for teaching purposes. The total number of CNC machines reported to be in use is 282. If this number is divided by the total number of industrial technology departments, the average would be 2 to 3 CNC machines in each department.

Many brand names of CNC lathe and milling machines are in use by industrial technology departments nation wide. Therefore, no particular brand name can be identified as most frequently used for teaching CAM. The results of this investigation indicate that both panel controlled and personal computer controlled devices are used to operate this equipment.

CNC equipment controlled by personal computers are more desirable to use, since such equipment can readily be integrated with popular industrial standard CAM software available on the

market. Such software makes the teaching of CNC programming more standardized because it has the ability to provide machine codes for different brands of CNC lathe and milling machines.

Question #4 What kind of software programs are being used for teaching CAM in industrial technology programs?

participants responding to this study indicated that many different kinds of CAM software are used in the industrial technology programs. Mastercam and Smartcam, which both are industrial standard software programs, are the most popular programs used for teaching computer aided manufacturing. A variety of other educational and industrial type CAD/CAM software programs, in smaller numbers, are also being used by industrial technology programs. Some of the industrial technology programs reported using more than one type of CAD/CAM software for their instructional purposes.

Question #5 What factors, if any, significantly limits the ability of professors in the teaching of computer aided manufacturing?

No singular factor can be identified as significantly limiting the teaching of CAM in industrial technology programs. Availability and ability to purchase software and CNC equipment are the factors of concern for some of the industrial technology programs. The least identified concern of respondents was lack of student interest. It is obvious that there is a great deal of motivation and interest shown by students in learning computer aided manufacturing. Lack of professor/instructor training and student's background are not identified as a problem in teaching of this subject.

Summary

There is little doubt that industrial technology programs nation wide are aware of the importance of computer aided manufacturing and automation in their programs. This is indicated by the number of classes related to CAM, sequence of courses, CNC machinery, and the types of software programs implemented in teaching computer aided manufacturing. The trend taken by industrial technology programs toward teaching CAM is focused on implementing one-hundred percent automated manufacturing systems. This goal is being achieved through the integration of CAD/CAM, robotics, and developing flexible manufacturing cells.

Computer aided manufacturing has a great appeal for students and provides an excellent learning experience relevant to the industrial work environment. Proficiency in computer aided manufacturing is a necessary skill for employment in the manufacturing sector. This fact is recognized by both industrial technology professors and students.

Although CAM technology has been implemented widely in the curricular offerings of industrial technology programs, this study suggests that further research is needed to identify attitudes and perceptions of instructors and students in regard to effectiveness of learning this technology. results of such a study may provide guidelines for identifying, developing, and implementing appropriate CAM technology in the continuously changing industrial environment of the future.

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APPENDIX 1

Computer Aided Manufacturing
in Industrial Technology Programs

I. PROGRAM INFORMATION:

1. Do you teach computer aided manufacturing in your department?

   _____ YES _____ NO

   If yes, when did you start your program?

   Please indicate the number of years. _____.

2. What is the average student enrollment in your CAM and manufacturing courses? _____.

3. What is the total number of classes offered which relate to metal working and CAM in your IT program?
   _____ (please indicate number).

4. Which of the following courses are being offered in your IT program? (Please Check all that apply).

   _____ Introduction to Metals
   _____ Manufacturing Processes
   _____ Machine Tool
   _____ Computer Numerical Control
   _____ CAD/CAM
   _____ Cell Manufacturing (CIM)
   _____ Flexible Manufacturing System (FMS)

5. Please indicate, in numerical order, the subjects being taught in the manufacturing area of your IT program:

   _____ Introduction to metal working (Which includes properties of metals, blueprint reading, layout, measurements, etc.)
   _____ Introduction to machine tool (Which includes introduction to drill presses, band saws, lathes, milling machines, etc.)
   _____ Advanced machine tool technology
   _____ NC programming
   _____ CNC programming
   _____ CAD/CAM
   _____ Cell manufacturing (CIM)
   _____ Flexible Manufacturing Systems (FMS)

II. EQUIPMENT INFORMATION:

6. What existing CAM equipment is utilized in your IT program?

	Type of Machinery:	Number of Machines:	Name of the Manufacturer:
_____	Desktop lathe, controlled by a PC.	_____	_____
_____	Desktop mill, controlled by a PC.	_____	_____
_____	Industrial lathe, controlled by a PC.	_____	_____
_____	Industrial mill, controlled by a PC.	_____	_____
_____	Desktop lathe with control panel.	_____	_____
_____	Desktop mill with control panel.	_____	_____
_____	Industrial lathe with control panel.	_____	_____
_____	Industrial mill with control panel.	_____	_____

7. Your CAM equipment is located in: (Please Check)

_____ a designated CAM laboratory.
_____ the same area with other metalworking equipment.

8. Which of the following software programs are used for teaching CAM in your IT program? (Check all that apply)

Software Available	Number of Copies
_____ Mastercam	
_____ Series 1400 CNC control	_____
_____ Spectralight CAD/CAM software	_____
_____ D&M CAD/CAM software	_____
_____ Dyna CAD/CAM software	_____
_____ Other (Indicate)	_____
_____	_____
_____	_____

9. Which of the following factors do you feel significantly limits the extent to which you are able to teach CAM in your IT program:

	Least Significant				Most Significant
Availability of CNC equipment	1	2	3	4	5
Availability of software	1	2	3	4	5
Lack of training	1	2	3	4	5
Lack of student interest	1	2	3	4	5
Lack of student background	1	2	3	4	5

10. General Comments:

Thank you for your time and for the information you provided. Please place the completed survey in the self addressed postage paid envelope provided and return to:

Department of Industrial Technology
Eastern New Mexico University
Station # 11
Portales, NM 88130