A National Probability Survey on Education and Training for CAD/CAM

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Abstract—**Substantial pragmatic attention has been focused on the recent implementation of computer-aided design/computer-automated manufacturing (CAD/CAM) by discrete parts manufacturers. Despite this attention, little systematic data has been obtained about the training programs used to help prepare the workforce for CAD/CAM. In this study, manufacturing facilities having CAD/CAM in place were surveyed to assess their training priorities. In addition, factors explaining variations in training programs were explored. The results pertaining to a description of the training programs indicated that not all plants have seen the need for training (especially those which are smaller and have less equipment automated). Moreover, for those who have training programs, the programs were found to teach generic as well as traditional machine skills to a variety of occupations. The results pertaining to factors explaining variations in training programs indicated that an organization's decision to adopt a CAD/CAM training program was primarily related to three factors: the amount of CAD/CAM equipment installed, plant size, and relative size of manufacturing operations (integration of the CAD/CAM equipment and market variables were less influential). Moreover, an organization's decision about scope or extensiveness of the training was related to somewhat different and more varied factors including the degree to which the CAD/CAM equipment is integrated and growth in the firm's industry. Implications of these findings for research and practice are discussed.**

BACKGROUND

ADVOCATES of computer-aided design and computer-automated manufacturing (CAD/CAM) technologies tout the many benefits of these innovations. However, new technologies can only yield productivity gains if workers are prepared for the requirements of the technologies; moreover, workers can only be adequately prepared if they are appropriately trained. A member of the Congressional House Science, Research, and Technology Subcommittee recently stated that he believes that American industry is unable to take advantage of the robotics revolution because of a lack of trained people [1]. Furthermore, a Bureau of Labor Statistics survey of machine tool manufacturers cited the lack of adequate training and preparation of workers as the principal obstacles to maintaining and increasing production levels with technological change [7], [8].

Clearly, training is an important issue as manufacturing plants install CAD/CAM. In this paper, a study is described that provides a systematic assessment across several hundred firms of the type of training they provide to workers involved with CAD/CAM equipment. By CAD/CAM is meant equipment used in a discrete parts production process that is computer-controlled and capable of multiple applications. Example technologies include CAD, robots, computerized numerical control (CNC), distributed numerical control (DNC), automated storage and retrieval systems (ASRS), and automated materials handling. Since these technologies form the building blocks for computer-integrated manufacturing (CIM), there has been considerable pragmatic concern about their successful implementation and how training can enhance this success.

Two training issues were of particular concern in this study: 1) the extent and scope of training for CAD/CAM and 2) factors explaining variations in training programs.

Extent and Scope of CAD/CAM Training

Econometric studies, case examples, and practical insight have suggested numerous ways in which the implementation of CAD/CAM will affect workers' skills. Production staff are expected to need increased conceptual skills, perceptual aptitudes, and the ability to read and write operating instructions [25]. Professional/technical staff are expected to need additional training in the production process, mathematics and the ability to visualize objects and motions in three dimensions [8]. Supervisors are predicted to need training in skills for organizing and integrating shopfloor operations, leadership skills to motivate workers on potentially boring jobs, and human relations skills to help workers adapt to the new technology [6], [26]. Finally, it has been predicted that strong basic skills in math, science, reading, and computer literacy will constitute the foundation for all new technology instruction [24].

The overarching theme for these predictions is that the skills needed to operate a factory with CAD/CAM equipment are dramatically different than the skills needed to operate a factory with conventional equipment. Thus, it was hypothesized in this study that the installation of CAD/CAM equipment would create a substantial need for in-house education and training activities. This need would be manifested by a majority of plants with CAD/CAM equipment in places reporting having some in-house training focused on adapting workers to the new equipment.

In addition to simply needing new skills, the installation of CAD/CAM equipment has effects that can reverberate throughout an organization [21], [24]. It can change the way managers schedule production runs, the way process engineers design tools, and the transfer of displaced workers to new

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jobs. Given these far-reaching effects, it was also hypothesized in this study that the need for substantial training with CAD/CAM would be experienced at all levels of the organization—from managers and professionals to displaced workers. Thus, plants with CAD/CAM training programs would report providing training to a considerable variety of occupational levels in the organization.

It is one thing to hypothesize that the implementation of CAD/CAM equipment creates a need for a specially focused training program; it is a totally different issue to hypothesize the specific skills needing training. For the operators of CAD/CAM equipment, functions previously performed by the operator are now controlled by the computer. As such, workers narrowly tied or knowledgeable only of the operations of a specific machine would be less useful to the organization. Thus, theorists have suggested that organizations with CAD/CAM would prefer workers with more flexible skills than workers have traditionally had in the past [17]. In addition to workers with flexible skills, workers (particularly skilled trades and professionals) who become acquainted with the workflow production process and how the equipment enhances this process are also expected to be particularly needed in organizations with CAD/CAM [21], [24]. Workers with such knowledge are able to optimize equipment utilization given workflow constraints as well as identify enhancements to the production process with the CAD/CAM equipment. In combination, these two characteristics of CAD/CAM equipment suggest that training programs for CAD/CAM would teach much broader skills than traditionally taught in in-house plant training programs. Such skills would range from basic science and engineering to a general understanding of the manufacturing process. Thus, it was hypothesized in this study that plants with a CAD/CAM training program would offer education and training not only in the operation of specific machines but in more generic skills and knowledge areas as well.

Factors Explaining Variations in Training Programs

While it was hypothesized that a majority of the plants with CAD/CAM equipment in place would have training programs to optimize the use of the equipment, variations were expected in whether and how much training was offered. Thus, a second issue addressed by this study was the identification of factors that could explain variations in training programs.

From the literature on technological change [28], factors explaining variations in the way organizations implement new technology can be viewed from three perspectives: market, organizational, and equipment. A market-based perspective suggests that implementation decisions are driven by market factors such as the value of products sold [1], [29] or wages of workers [4], [20]. For example, in describing GE's training program, Zukowski [31] indicated that the major reasons GE had the program was that it was cheaper by a 2.6 to 1 margin to retrain engineers and managers in the digital technology than to layoff and hire already-trained replacements. Moreover, plants with high value-added products may tend to be more profitable and thus able to invest in in-house training programs.

In contrast to a market perspective, an organizational perspective suggests that organizations' decisions about implementation are more likely to reflect characteristics of the organization than characteristics of the organization's industry or equipment. Such organizational characteristics might include workforce composition, size, or age of the organization [15], [28]. For example, Lusterman [20] and the Bureau of Labor Statistics [8] have found that large firms were more likely to have in-house training programs than small firms. This finding has been explained by the more extensive in-house resource base of larger firms as well as the opportunity larger firms have to capitalize on training activities in other parts of the organization.

Finally, an equipment-based perspective would suggest that implementation decisions—particularly training activities—are technologically driven. Certain types of equipment need certain types of training. For example, Hazelhurst *et al.* [16] found that the implementation of stand-alone NC machines—forerunners of CAD/CAM—may not necessitate extensive training. However, when equipment is linked with other equipment to create a more integrated production process, a need is created to have a more systemic perspective where problems and solutions on one issue are identified only as they relate to problems and solutions on other issues [9], [10], [21], [27]. Thus, from this view, organizational and market-driven forces would be less important than equipment factors such as the degree to which the equipment is integrated with other equipment.

In this study, the relative utility of these three perspectives for explaining variations in CAD/CAM training programs was explored. Two types of variations were examined: 1) variations in the decision to adopt a training program and 2) variations in the decision about the extensiveness of the training program once adopted. It was expected that variations in both of these training decisions could be explained by all three perspectives. For example, an organization's decision about whether to develop a CAD/CAM related training program for its workers as well as its decision about the extensiveness of the training program might be affected by the firm's size (from an organizational perspective), the wage scale of its workers (market), and the amount of CAD/CAM equipment installed. In addition, however, the extent of influence of these determinants as well as the direction of the influence may differ across the two training decisions. For example, the *larger* the plant, the more likely it may be to adopt a training program because it has the resources to do so; in contrast, of those plants with training programs, *smaller* plants may have more extensive programs (relative to their own size) since there are fewer people to train [15]. In addition, smaller plants tend to have less rigid operating styles and thus might more readily benefit from the flexibility provided by well-trained workers.

Research on determinants of training programs has primarily focused on identifying different determinants [28]. There has been little research, to the author's knowledge, on the *relative* influence of different determinants. Moreover, there has been no research, to the author's knowledge, which considers more than a single training decision, and examines the relative influence of different predictors for those decisions. Thus, in examining determinants of training programs, only a generalized expectation that their relative importance and direction might vary with the different training decisions could be advanced.

Since the three perspectives on determinants of training decisions each describe a whole host of variables, only a subset of the variables could feasibly be examined in a single study. For the organizational perspective, the variables of plant size, age, workforce composition, and relative size of manufacturing operations were used. Plant size (both as workforce size and sales) has been identified as a proxy for in-house availability of resources [15], [28]; firm age has been identified as a proxy for organizational rigidity toward change (older firms are more bureaucratic and thus rigid) [15], [28]; and workforce composition (as the proportion of hourly workers in the plant) and the relative size of manufacturing operations (as the proportion of workers in manufacturing) provide different measures of the importance of manufacturing in the plant. Plants with a greater portion of their revenue and expenses deriving from manufacturing were expected to benefit more from adequate training programs and were thus more likely to adopt and develop such programs.

The market perspective is best assessed using descriptions of the industry conditions confronting plants implementing CAD/CAM. Such descriptions include the value-added of goods sold in the industry, the average capital expenditures of plants in the industry, the wage scale of hourly workers in the industry, and the average employment level of hourly workers in the industry. Markets with high value-added were expected to have plants with more assets for training; markets with large capital expenditures were expected to have plants with a greater need for training; and markets with high employment rates and high wage scales were expected to have plants which depended more on their ability to retrain their own workers rather than hire from outside.

Finally, the equipment perspective can be described as both the amount and type of equipment installed. The type of equipment was described by its degree of computer-integration with other equipment.

The variables used to describe the three perspectives were not selected to represent the complete construct posed by the perspective. Rather, they were used because the literature identifies them as important determinants and information on them could be gathered within the constraints of the study.

Summary of Hypotheses

In summary, five hypotheses were advanced:

1) The implementation of CAD/CAM involves enough new skills that there will be a substantial number of plants with CAD/CAM which have in-house programs to train their workers.
2) The effects of implementing CAD/CAM reverberate throughout enough of an organization that CAD/CAM-related training will be provided to all occupational levels.
3) Since concern for technological obsolescence and the desire for cross-training is increased with the implementation of CAD/CAM, training programs will teach generic skills as well as specific machine operations.
4) Organizational, market, and equipment factors will help to explain variations in organizations' decisions to *adopt* a CAD/CAM training program. The relative influence of the factors is not clear.
5) Organizational, market, and equipment factors will help to explain variations in organizations' decisions to develop an *extensive* CAD/CAM training program. The relative influence of the factors is not clear.

METHOD

Training for CAD/CAM was examined using a combination of two data sources. The first source was a 20-min telephone survey conducted in August 1982 of a national probability sample of firms. Three hundred and ninety three manufacturing establishments were selected in a multistage probability sampling approach stratified by major industry type, size, and regional location from a population of 24 142 establishments. A 76-percent response rate yielded a usable sample of 303 establishments. Three manufacturing industries were selected—transportation equipment (Standard Industrial Classification (SIC) 37),[1] electric and electronic (SIC 36), and industrial metalworking machinery (SIC 35)—since the nature of their production processes (small batch) make them the most likely users of CAD/CAM technology [14]. Plant representatives (including plant managers, human resource directors, and chief executive officers) were interviewed by telephone concerning the use of various CAD/CAM technologies. Use of CAD/CAM was assessed by having respondents indicate the percent of manufacturing equipment on the production floor that was computerized and whether the plant had in use any of six computer-automated technologies (robots, CNC, DNC, CAD, ASRS, and AMH). Those firms indicating that they had some CAD/CAM equipment in place on the shopfloor were asked questions to test study hypotheses. In total, 44 percent of the 303 plants interviewed had some CAD/CAM equipment in place and were therefore asked questions about their education and training for CAD/CAM.

To test the hypotheses about the extent and scope of training programs for CAD/CAM, plant respondents were asked close-ended questions about whether or not they offered an in-house company-supported training program focused on the CAD/CAM equipment. If they offered such a program, they were asked to indicate which of eleven skills were covered by the training, which eight occupational groups received instruction, and miscellaneous other questions (e.g., percent of workforce receiving training, sources of training, etc.). Specific phrases used in the survey are presented later in the section on results as part of Table I.

To test the hypotheses about the relative importance of different factors for explaining variations in training programs, equipment and organizational factors were assessed by the survey. Equipment factors were measured as prevalence of new CAD/CAM equipment (i.e., the percent of production equipment that was computer-automated) and level of integra-

[1] Details of the sampling methodology can be found in [23].

tion of the new equipment (i.e., proportion of computer-automated equipment that was integrated via computer-based linkages). Organizational factors were measured as size (composite of company gross sales and total number of employees in 1981), workforce composition (percent of hourly workers in the plant relative to the total number of workers), firm age (year company founded) and size of manufacturing workforce (proportion of plant workforce involved in manufacturing operations).

Finally, to assess market factors, a second data source was identified and combined with the survey data. The data source was the Census Bureau Annual Survey and Census of Manufacturers which contains industry-level data across time on hourly employment levels, hourly wages, value-added, and capital expenditures, among other things. Data on the variables as of 1980 (two years prior to the survey) as well as for the period between 1970 and 1980 were obtained for all four variables at the level of each plant's four-digit SIC, and adjusted for constant dollars. Value-added and capital expenditures were highly correlated ($r = 0.85$) as were hourly employment levels and wages ($r = 0.87$). Thus only value-added of goods sold and hourly wages were included in the analysis.

The combined survey and Census Bureau data were weighted up to their representation in the population. The 303 plants were weighted to 24 142 since the plants had been intentionally and proportionately sampled to represent the population, rather than randomly and independently selected. In such situations, when the purpose is to make judgments about the population, weighting the sample is preferable [12], [19].

Results

Description of CAD/CAM Training

The first hypothesis predicted that there would be a substantial number of firms with CAD/CAM which have training programs for adapting workers to the CAD/CAM equipment. The survey indicated that of those plants with CAD/CAM, a training program for CAD/CAM equipment was sponsored by 45 percent, or a weighted group of 4604 plants. This percent is comparable to a 1982 *Plant Engineering* survey which found that slightly under 50 percent of the responding firms indicated having training for skills related to automated equipment [2]. Moreover, on the average, 25 percent of the workforce at a plant received CAD/CAM training. Compared to results of a 1975 Conference Board survey which found 13 percent of the production workforce receiving any training [20], the plants in this survey with CAD/CAM were training a larger proportion of their workforces.

The second and third hypotheses predicted that training programs for CAD/CAM would be focused on a variety of occupations and skills. Table I presents the responses of plants with CAD/CAM-related training concerning the occupations addressed and skills taught by the training.

Apparent from Table I is that a range of occupations is being covered by the training programs. Moreover, about half of the plants with CAD/CAM training provided the training to all occupational groups. Thus, the fact that training for CAD/CAM goes beyond the machine operator suggests that, as hypothesized, many plants implementing CAD/CAM train a diverse audience in order to achiev[illegible] desired benefits from their new equipment. Managers, re[illegible]rers, and engineers, as well as workers displaced by the equipment need retraining. The inclusion of supervisors in the training is particularly

TABLE I
DESCRIPTION OF CAD/CAM TRAINING PROGRAMS
(Weighted $N = 4604$)[1]

	Percent[2]
Occupational Groups Receiving E&T	
a. Shopfloor staff who assemble, handle or load material	59%
b. Individuals who count materials (pre-production) or distribute products (post-production)	47%
c. Shopfloor staff who set up the equipment	61%
d. Shopfloor staff who operate equipment	86%
e. Repair and maintenance staff	61%
f. Production engineers and programmers	74%
g. Design engineers and programmers	44%
h. Supervisors or managers of shopfloor personnel	77%
Skill or Knowledge Areas Covered	
a. Basic physical science	34%
b. Basic reading, writing & arithmetic	44%
c. Specific machine operation	89%
d. Maintenance and troubleshooting	74%
e. Computer programming	74%
f. Problem-solving (e.g., making use of objective data for decisionmaking)	69%
g. Developing sufficient knowledge of the entire manufacturing process in order to work with others in different departments and at different levels	69%
h. Human relations (e.g., dealing with worker morale)	53%
i. General knowledge of safety procedures	95%
j. Knowledge of basic engineering concepts	52%
k. General knowledge of technological advances in manufacturing	82%
Format of E&T	
a. Apprenticeship	49%
b. Single courses	69%
c. Series of courses	59%
Sources for Delivering E&T	
a. Inhouse instructors	80%
b. Training industry and management consultants	47%
c. Traditional educational institutions	54%
d. Proprietary educational institutions (e.g., ITT, Control Data)	21%
e. Vendors or manufacturers of computer-automated equipment	87%
f. Unions	5%
g. Other gov't sponsored instructional programs (e.g., Private Sector Initiative Program)	13%

[1]Represents 45% of the 10,000 plants with CAD/CAM indicating they had an inhouse CAD/CAM training program.

[2]Percent of plants with CAD/CAM training indicating that their training programs were characterized by each of the following.

comforting given research that has identified the first-line supervisor as a major influence on workers' acceptance of automation [3].

Despite the existence of many plants which provide training to all occupations, Table I also indicates that there are many plants which do not provide training to all or even most of the occupational groups. On the average, only two occupations were served by each plant with CAD/CAM training. Occupations receiving the least attention were workers who count, distribute, assemble, load, or handle materials, as well as design engineers and programmers. Design staff probably received little training due to a comparatively small diffusion of CAD. However, the relatively small emphasis on retraining of displaced workers to operate CAD/CAM equipment implies that CAD/CAM is generally implemented such that instead of training displaced workers to operate the new equipment, in many plants the displaced workers are either laid-off or shifted to other parts of the plant not requiring new training.

In terms of skills and knowledge areas covered by the training, the average plant provided training in three skills. Skills taught by most plants were safety, specific machine operation, and a general knowledge of technological advances in manufacturing. Skills in maintenance, programming, problem-solving, and knowledge of the manufacturing process were also taught by 69 percent or more of the plants. Thus, as hypothesized, training programs for CAD/CAM are much broader than a traditionally narrow focus on specific machine operation. More generic skills such as problem-solving, and general knowledge of technology and manufacturing are areas which have traditionally received little attention in industry training classes. Apparently, the practical dictum for the need to sufficiently train the workforce to understand enough of their workplace to integrate and optimize the use of the new CAD/CAM equipment has been heeded by many companies today.

While several skills were taught in the average CAD/CAM training program, not all of the generic skills queried were taught by a large number of firms. Basic knowledge of science, engineering, and the 3 R's were left to be taught elsewhere (e.g., possibly through educational institutions), as was training in human relations (e.g., skills needed for handling worker morale problems, communication, and group processes).

In addition to skills and occupations covered, plant respondents were asked to indicate the source they used to deliver training for CAD/CAM. There were no predictions about which source would be most popular; however, it is interesting to note the heavy reliance of plants on both in-house instructors and vendors. Jacobs [18] has found similar results in his survey of Michigan auto suppliers with CAM, CAD, and SPC. This reliance on vendors has been criticized by many (e.g., [11], [13]) since vendor programs are neither customized nor easily modifiable as the organization's needs change. However, given the large number of plants (80 percent) using both in-house and vendor training, these plants may have overcome the problems of vendors by using in-house staff to modify the vendor training to better serve the organization's own interests.

In sum, these results suggest about half of the plants instituted training programs with CAD/CAM, and that the training was provided to more than machine operators, teaching issues much broader than knowledge of how the specific machines operate. Moreover, Table I clearly indicates substantial variation in organizations' approaches to CAD/CAM training; some have no training while others have quite extensive programs. In the remaining discussion of the results, possible reasons accounting for these variations in the training programs are explored.

Factors Explaining Variations in Training

The fourth and fifth hypotheses focus on factors potentially explaining some of the variation in CAD/CAM training programs. Two types of variations were explored: an organization's decision to *adopt* an in-house CAD/CAM training program and an organization's decision about the *extensiveness* of the training program once adopted.

The hypothesis about factors related to the first decision—that of the adoption of the training program—was addressed with regression analyses. Then, given the restricted range (i.e., Yes/No) on the dependent variable, discriminant analyses were used to confirm the regression results. Since the question concerned the decision to adopt CAD/CAM training, the sample size was the (weighted) 10 000 plants having any CAD/CAM on their manufacturing floor.

For the weighted sample of 10 000 plants, a correlation matrix (see Table II) among the predictor variables was computed. This matrix yielded several strong relationships. In particular, plants in industries with high value-added products were very likely to also be in industries having high wages for production workers (r's = 0.90 to 0.94); and larger plants were likely to also be older, with *fewer* manufacturing employees relative to the entire plant workforce (r's = -0.56 and -0.41). The inverse relationship between plant size (measured as sales and workforce size) and proportion of the plant workforce in manufacturing is probably attributable to the fact that larger plants have more nonmanufacturing support staff in such functional areas as finance, sales, distribution, R&D, and training. Thus, in many larger plants manufacturing operations constitute a less central portion of plant expenditures and resources.

Since high intercorrelations create a suspicion of multicollinearity, the likelihood of multicollinearity was explored. To detect multicollinearity, eigenvalues from principal components analyses were examined and variance inflation factors or VIF's were inspected (techniques recommended by [5] and [30]). These analyses indicated that using the VIF technique, production wages and value-added were linearly dependent (i.e., VIF's ranged from 9.1 to 12.5 with Wilson [5] recommending a cutoff for dependence of no higher than 10). Moreover, using a principle components analysis, several non-zero eigenvalues were identified. Loadings of variables on those factors indicated sources of collinearity to include plant total size with age, and plant total size with size of manufacturing operations. Thus, rather than drop or combine variables initially intended as separate concepts, a series of

TABLE II
CORRELATION MATRIX FOR VARIABLES PREDICTING DECISION TO ADOPT TRAINING

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Equipment integration (1)	1.0									
Equipment prevalence (2)	.35	1.0								
Prop hrly workers (3)	-.08	-.20	1.0							
Size (4)	-.10	.11	-.06	1.0						
1980 wage (5)	.09	.15	0	.09	1.0					
1970-80 wage growth (6)	.15	.21	.06	.39	-.04	1.0				
1980 value (7)	.11	.17	-.12	.17	.91	.10	1.0			
1970-80 value growth (8)	.15	.17	.01	.37	-.17	.94	.02	1.0		
Founding year (9)	.22	.08	-.19	-.56	-.03	-.22	.02	-.17	1.0	
Relative size of mfg. opers. (10)	.14	-.05	.06	-.41	-.26	-.06	-.29	-.04	.28	1.0

regression analyses were conducted on different sets of relatively nondependent variables.

Results of the regression analyses for the training adoption decision are presented in Table III. The results indicate that 27-30 percent of the variance in training adoption decisions were accounted for by the variables. That is, almost one-third of the variation—an amount considered quite large for behavioral research—was attributable to the included variables.

A review of the standardized regression coefficients across the six regression equations in Table III indicates the relative importance of the variables. For the equipment factors, the degree to which CAD/CAM equipment is integrated with each other had little effect on a plant's decision to adopt a CAD/CAM training program. However, the amount of equipment automated on the shopfloor had a great effect. In other words, decisions to adopt CAD/CAM training are made based to a much greater extent on the amount of CAD/CAM equipment purchased rather than whether or not that equipment has been linked to other equipment or allowed to remain as stand-alone machines. One plausible reason for this finding may be that plant managers choose to respond to training needs based more on the number of people directly affected by the equipment than the way in which they are affected. That is, when equipment affects too few employees, no matter how dramatic the change, the benefits of training may be insufficient to outweigh the costs.

The remaining factors had a relatively smaller contribution of factors than prevalance to explaining decisions to adopt (i.e., no more than 10 percent of variance in the decision to adopt was accounted for by market and organizational factors versus 20 percent by equipment factors). The most stable of these contributors across the regressions included two organizational variables: total plant size (larger plants were more likely to have CAD/CAM training) and relative size of manufacturing operations (plants where there were *fewer* manufacturing workers were more likely to have CAD/CAM training). The inverse relationship between relative size of manufacturing and training adoption may be interpreted in three ways: 1) plants with fewer manufacturing workers are larger and thus this relationship is a restatement of the importance of size on adoption decisions, 2) plants with smaller manufacturing operations adopt training since training is less costly when relatively fewer workers are involved, or 3) plants with smaller manufacturing operations more readily adopt training because they have relatively larger numbers of support staff to help deliver the training. The latter two interpretations suggest that training is adopted because it is more manageable to do so in plants with a smaller portion of the personnel in manufacturing.

TABLE III
REGRESSIONS PREDICTING DECISION TO ADOPT TRAINING

Equation	Variables	Stdized B	Adj R^2
1	Prevalence of equipment	.41	
	Integration of equipment	.05	
	Plant size	.33	
	Prop hrly workers	0	
	1980 value-added	.02	
	1970-80 value growth	-.02	.31
2*	Prevalence	.40	
	Integration	.04	
	Size	.30	
	Prop hrly workers	-.01	
	1980 wage	.02	
	1970-80 wage growth	.05	.31
3	Prevalence	.47	
	Integration	.01	
	Founding year	-.09	
	Prop hrly workers	.04	.28
	1980 value-added	.07	
	1970-80 value growth	.14	
4*	Prevalence	.45	
	Integration	.01	
	Founding year	-.07	
	Prop hrly workers	.01	.30
	1980 wage	.05	
	1970-80 wage growth	.05	
5*	Prevalence	.42	
	Integration	.04	
	Relative size of mfg opers	-.16	
	Prop hrly workers	.03	
	1980 value-added	.03	
	1970-80 value growth	.13	.25
6	Prevalence	.42	
	Integration	.04	
	Relative size of mfg opers	-.16	
	Prop hrly workers	.04	
	1980 wage	.01	.27
	1970-80 wage growth	.18	

*These sets of variables were included in the later discriminant analyses.

The relative importance of these variables and their ability to correctly classify firms into adopters and nonadopters of training were confirmed with a discriminant analysis. In this analysis, 77–83 percent of the cases were classified correctly, indicating substantial improvement over chance.[2] Table IV presents the results of the discriminant analysis.

These findings are contrary to those hypothesized. It had been anticipated that plants would adopt CAD/CAM training programs in partial response to all three factors, including market variables. These findings did not support that expectation since market factors had relatively little importance in the adoption decision.

These findings, however, did offer partial support for the hypothesis since both organizational and equipment factors were important. That is, plants were more likely to adopt CAD/CAM training programs when they install more CAD/CAM equipment, when they are sufficiently large to have resources to bring to bear on training, and when their manufacturing functions represent a smaller and therefore more manageable part of the plant's entire operations.

In addition to variations in whether or not organizations adopt a CAD/CAM training program, organizations in the sample varied in the scope of their training effort. An index of the scope or extensiveness of training was computed from the survey responses. The index was composed of the number of occupations and skills taught by the plant, level of supplementary benefits for training provided by plant management, percent of plant workforce trained, number of in-house instructors, and provision of a program of interrelated courses as opposed to sporatically-offered individual courses. A Cronbach's alpha of 0.75, supported by a singular factor in a factor analysis indicated that the index was statistically supportable. The index was standardized on those plants with a CAD/CAM training program so that a score of 0 indicated an average amount or scope of training for the sample and a positive (negative) score indicated above (below) the average.

For analysis on the extensiveness of the training programs, only those plants with a training program in place were examined (weighted sample of 4600). As with the previous analysis, multicollinearity prevented the inclusion of all variables in a single regression equation. However, redoing the multicollinearity analysis on the smaller sample indicated that total plant size and relative size of manufacturing operations were no longer linearly dependent and thus could be included in the same equation. As before, regressions on different combinations of variables were conducted.

Results of the regression analyses are presented in Table V. As indicated in the table, 30–34 percent of the variance in extensiveness of training was accounted for by the variables, again a large amount for behavioral science research.

Comparing the relative importance of the variables in the regression equations for training *extensiveness* with those for the decision to *adopt* a training program yields several findings. First, integration of CAD/CAM equipment was more important to determining the extensiveness of a CAD/CAM training program than in determining whether or not to adopt a program. Integrated equipment apparently demands increased attention to a broad range of skills. These skills cannot be taught with a minimal, narrowly focused training program.

Second, market variables help to explain scope of training much more so than they explain the decision to adopt. Growth in value-added of goods sold seemed to provide the financial base to retrain larger numbers of workers, while a growth in production wages over time tended to provide the impetus to have broader programs. As labor becomes more expensive,

TABLE IV
DISCRIMINANT ANALYSIS OF DECISION TO ADOPT A TRAINING PROGRAM

DISCRIMINANT FUNCTION

Eigenvalue	Canonical Correlation	Wilks Lambda
.34	.50	.75

STANDARDIZED FUNCTION COEFFICIENTS

Prevalence of equipment	.87
Integration of equipment	.10
Relative size of mfg opers	-.36
Prop hrly workers	.06
1980 value-added	.06
1970-80 value growth	.29

GROUP	GROUP CENTROID	% CORRECT CLASSIFICATION
No CAD/CAM training	-.88	83%
CAD/CAM training program in place	.39	77%
	Total	79%

TABLE V
REGRESSIONS PREDICTING SCOPE OF TRAINING PROGRAMS

Equation	Variables	Stdized B	Adj R^2
1	Prevalence of equipment	.19	
	Integration of equipment	.31	
	Size	.33	
	Relative size of mfg oper	-.01	
	Prop hrly workers	-.12	
	1980 value-added	-.11	
	1970-80 value-growth	.10	.30
2	Prevalence	.20	
	Integration	.31	
	Size	.33	
	Relative size of mfg oper	-.03	
	Prop hrly workers	-.09	
	1980 wage	-.17	
	1970-80 wage growth	.06	.31
3	Prevalence	.02	
	Integration	.45	
	Founding year	-.12	
	Prop hrly workers	-.20	
	Relative size of mfg oper	-.02	
	1980 value added	-.17	
	1970-80 value growth	.19	.33
4	Prevalence	.06	
	Integration	.43	
	Founding year	-.12	
	Prop hrly workers	-.16	
	Relative size of mfg oper	-.04	
	1980 wage	-.26	
	1970-80 wage growth	.12	.34

[2] Statistical tests assessing the statistical significance of group differences could not be done because, as explained earlier, the weighted sample size inflates *F*-values.

the costs and risks associated with hiring new employees increases. Therefore, efforts to train multiple occupations in multiple skills among the existing proven workforce may be preferred.

Finally, organizational variables also help to explain the extensiveness of in-house training programs as they did with the decision to adopt. The larger the plant size, the more resources the plant apparently had for developing and conducting the training. Older firms were also more likely to have extensive training programs. This was surprising because younger firms were expected to be less rigid and thus more open to extensive programs. Perhaps older firms offer more extensive programs because they have more resources to do so or because they have a more extensive experience base from is needed by a relatively large number of people compared to the entire operations but when it is more manageable to do so (either because relatively few people need the training or because sufficient support staff are available to help develop the training).

The importance of these three variables for predicting training adoption decisions is particularly interesting given those variables that were not important. Level of integration of the equipment is relatively unimportant; that is, firms implementing highly-integrated manufacturing cells are not more likely to adopt a training program than firms installing a series of islands of automation, provided the amount of equipment installed was the same. Perhaps what may be occurring here is a step function rather than a linear relationship between equipment and training adoption. That is, below some amount or type of equipment installation, training is not needed; upon reaching a minimal threshold of the amount of equipment installed, a training program is needed regardless of the type (e.g., integration) of the equipment.

It is also of interest to note that market factors were relatively unimportant predictors of the training adoption decision. Apparently, organizations do *not* decide to develop a training program because it would be too expensive to hire new workers (rather than train the old) or because they have performed well in the marketplace and want to reinvest their profits in training. Clearly, this study has not examined all market variables; moreover, market variables were measured at the industry rather than organizational level. Thus, further research is needed to assess the viability of a market perspective for explaining training adoption decisions.

Finally, while some organizational variables were important predictors of training adoption, other variables were not. Moreover, additional organizational factors such as the role of training-oriented managers or the history of training in an organization were not examined here. Thus, what this study indicates is that organizational variables are important. A closer examination of how these variables interact with equipment variables is needed.

The variables examined in this study explained about one-third of the variance in training adoption decisions. While this amount of explanation is quite high for behavioral science research, there is much room for improvement. For example, the failure to adopt training can be attributed not only to a lack of need (i.e., equipment factor) and lack of ability (i.e., organizational factor), but also to a lack of desire (.e., philosophical opposition to training). Research measuring such additional factors are needed.

Type of CAD/CAM Training Adopted

Among the 45 percent of plants adopting CAD/CAM training, several patterns describing the training programs were identified. Results of the survey indicated that the CAD/CAM training programs were more broad-based than training programs for traditional equipment. Over one-half of the programs provided training to all occupations and about two-thirds provided training not only in traditional skills (i.e., safety, specific machine operation, and maintenance), but in more generic skills as well. Generic areas taught included which to develop such programs. Finally, plants with more salaried workers had more extensive programs, contrary to expectation. One possible reason may be that, since plants were defined as having a larger training program when they provided training to numerous occupations and skills, extensive programs were more likely to be found among those firms that had sufficient numbers of both salaried and hourly workers to make such broad programs worthwhile.

In sum, these results suggest that prevalence of equipment as an equipment factor, and total plant size and relative size of manufacturing operations as organizational factors, were important predictors of the training *adoption* decision. In contrast, multiple variables from all three perspectives were important for predicting the *extensiveness* of the training program.

Discussion

The results of this study provide information pertaining to organizations' decisions to adopt an in-house CAD/CAM training program and their decisions as to the focus of that training. As such, these results have several implications for managers implementing CAD/CAM. These implications will be discussed at the close of this section.

Adoption and Scope of CAD/CAM Training

In this study, a national probability sample of manufacturing plants was surveyed for their use of CAD/CAM equipment and the training programs they used to adapt workers to the CAD/CAM equipment. The survey indicated that 45 percent of the plants with CAD/CAM had a training program.

To judge if 45 percent is high or low is difficult without a comparison sample of plants without CAD/CAM. Nevertheless, from other surveys conducted on plants having only traditional equipment [20], 45 percent is somewhat higher. However, 45 percent is far short of the commonly held expectation that the implementation of CAD/CAM will create a need for new and specially focused training.

Why aren't training programs adopted by more than half the plants with CAD/CAM equipment? Results of this study indicate that at least one reason concerns the amount of CAD/CAM equipment installed. With less equipment in place, informal on-the-job training provided after initial training by the vendor may be sufficient for optimal machine utilization;

however, as more equipment is installed, such a strategy appears no longer to be appropriate.

Another reason why CAD/CAM training programs are not developed appears to lie with different measures of organizational size. Larger organizations tend to have more in-house resources such as training departments, training experience, and training budgets. For smaller organizations, the costs of starting a training program specifically focused on CAD/CAM are much greater.

A final reason found in this study for plants not starting a CAD/CAM training program appears to be the relative size of manufacturing operations in the organization. It had been expected that the larger the relative size, the greater the perceived need for training. However, the results were the inverse. Apparently, organizations adopt training not when it problem-solving, general knowledge of technological advances in the plant, and knowledge of manufacturing processes to understand how the new technology fits in.

It is interesting to note what skills were *not* taught by plants. These included "human relations" skills, 3 R's, and basic science and engineering. This finding was surprising since quality control demands basic math knowledge; maintenance on CAD/CAM relies on rudimentary knowledge of engineering (e.g., hydraulics); and such human relations skills as group process, communication, and leadership were expected to be essential with CAD/CAM. Perhaps these skills are indeed not needed with CAD/CAM as much as other skills. Or perhaps these skills are only needed with certain types of CAD/CAM equipment (e.g, CIM). Or perhaps organizations have left the acquisition of these skills to other media, e.g., formal educational institutions for the basic skills and informal apprenticeships and selection procedures for the human relations skills.

While many CAD/CAM training programs taught many skills to a variety of occupations, there was substantial diversity in the scope of the training effort. An examination of variables explaining differences in scope of training indicated that two of the variables (equipment prevalence and total plant size) found to be important predictors of the decision to adopt training were also important predictors of the extensiveness or scope of training adopted. However, in addition, other variables from all three perspectives were also important for the extensiveness decision. That is, extensive training programs were more likely to exist in larger and older plants, which have experienced some market growth over the past decade and which have greater amounts of integrated equipment.

Thus, these findings suggest that the decisions about the focus of training result from a far more complex array of factors than decisions about whether or not to develop the program. The decision of scope rests on how integrated the equipment: the more integrated, the more training. The decision also rests on past growth; a good year or two creates sufficient optimism to invest more extensively in human resources. Finally the decision rests with characteristics of the organization: larger and older plants have more resources and expertise to develop more extensive programs.

These variables explained one-third of the variation in scope of training. Thus, again, there is much room for improvement. Of particular urgency is research in three areas. First, a systematic analysis of what skills are needed with different types of CAD/CAM equipment must be conducted. This study has described the skills trained. What is essential is to juxtapose these findings of what skills are trained on results of a systematic task analysis of a large number of jobs across many organizations both before and after different types of CAD/CAM equipment are installed. Thus, a much clearer understanding of the training gaps would be achieved.

A second area of research concerns the importance of training basic and generic skills to multiple occupations. Of particular concern is the cost-benefit ratio of providing extensive training to a workforce that frequently transfers jobs and organizations. Prescribing that organizations adopt extensive training ignores these realities. Research that helps to identify ways to "cut corners" on training without cutting benefits are necessary. Such research would need to consider ways of using the organizational context as part of an ongoing training program as well as community resources as part of a training resource network. Such systematic approaches to training would nicely complement the systemic approach advocated for managers installing CAD/CAM.

Finally, these results suggest that a much more complex model is needed of factors predicting the scope of an organization's training effort. Such a model might, for example, propose that equipment factors establish the initial need for training, and market growth factors provide the ability or optimism to offer the training, but that the training focus and scope reflect characteristics of the organization more precisely than the equipment or industry. This is an ambitious but highly plausible model in need of testing.

Implications for Managers Implementing CAD/CAM

From this study, suggestions can be derived for minimal training programs necessary with CAD/CAM. At a minimum, both shopfloor supervisors as well as machine operators need to be trained. This study would suggest that, in addition to machine operation, these supervisors need to be taught information about manufacturing processes at the plant and an understanding of where the technological advances fit in the corporate strategy and manufacturing process. Moreover, skills to be taught to operators of CAD/CAM also must go beyond specific machine operation. Offering training in safety procedures as well as a general knowledge of technological advances in manufacturing provide the employee exposed to CAD/CAM a better understanding of proper expectations for the new equipment.

The data described here also suggest that the precise composition of the CAD/CAM training program will be determined in large measure by decisions made about the equipment itself. The more equipment purchased, the more likely an extensive training program will be considered. Integrated equipment will also create a need for more extensive training. With CNC, machine-related training may be sufficient; however, with integrated equipment (e.g., automated materials handling), a broader range of skills and occupations will be touched. Knowledge of the manufacturing process and advances in technology become particularly important with integrated equipment.

Finally, the analysis suggested that, holding the automation of the plant constant for the moment, not all plants will choose to adopt a training program. The choice to adopt, while based primarily on the amount of equipment purchased, will be based in part on the plant's total size and relative size of its manufacturing operations. This may prove problematic for the small firm as well as single-function manufacturing plants which may be as much (if not more) in need of training than larger, multifunction plants. Simply because the in-house resources are not as easily available should not be an excuse to ignore the training needs under CAD/CAM. For example, in a study on successful implementations of CAM, Ettlie [11] found that training properly selected participants during the implementation process was crucial for success. Since smaller plants depend dramatically on the skills of their workforces, they in particular, cannot afford inadequate preparation and training. In addition, single-function plants centered around manufacturing are even more dependent than multifunction plants on the adequate preparation of manufacturing personnel. As such, to not train the workforce because of inadequate in-house support staff or because of high costs associated with training large numbers of people may be the wrong reasons. Therefore, despite costs associated with training, the lack of any CAD/CAM training for these plants may be short-sighted. Further research will tell.

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